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APPLIED MECHANICS REVIEWS

VOL. 10, NO. 12 MARTIN GOLAND *Editor* DECEMBER 1957

THE AREA RULE

K. OSWATITSCH

DIRECTOR OF THE INSTITUTE FOR THEORETICAL GAS DYNAMICS OF THE DEUTSCHE VERSUCHSANSTALT FÜR LUFTFAHRT E. V., AACHEN, GERMANY

THE practical significance of flow at transonic airspeeds has been increased during the past decade. With a mixture of subsonic and supersonic flow fields around flying bodies, very interesting but very difficult problems are posed for the theoretician as well as the experimenter. Even though transonic flow problems contain intricate phenomena and complicated theories, some simplified analyses could gradually be found whose validity is very wide. All these simple theories belong to bodies of low aspect ratio, i.e., to those slender bodies which are important for flight with sonic speed. According to M. M. Munk (1), the low speed cross flow is practically incompressible. With this idea, R. T. Jones (2) first found simple forms of lift distribution on pointed low-aspect-ratio wings, and, later on, several rules about the pressure distributions and drag properties of nonlifting wings were obtained. The later results are generally known as the "area rule." The present paper discusses these works in the order of their publication.

In a distance of a few diameters from a slender body flying with subsonic velocity the air is rather undisturbed. In other words, the disturbances decrease much more rapidly in a direction across the flight than in that along the flight. The flow field in the neighborhood of each cross section of the body can therefore be described by the Laplace equation for the velocity potential. The validity of "the incompressibility of flow in cross planes" increases as the speed approaches the sonic value because the stream tube is nearly incompressible in this range. It should be noted that with respect to the incompressibility condition one should distribute the cross-sectional areas of the body, the wing and other surfaces evenly along its longitudinal direction. For instance, if possible, engine nacelles and wings are to be placed ahead or behind the maximum thickness of the fuselage. This idea is based on a patent of the Junkers company from the year 1944. It is checked by experiments regarding the favorable position of engine nacelles with swept forward wings and speeds up to 0.90 of the sound velocity. This work has recently been published by O. Frenzl (3), one of the patent owners.

The calculation of the pressure distribution on a nonlifting body proves to be more difficult than the calculation of a lift distribution on a lifting delta wing, according to R. T. Jones. The incompressibility of flow in cross planes is valid only in the neighborhood of the body. The lifting effect up to a certain section corresponds to the effects of a system of contrarotating vortices further downstream from the section. Perpendicular to the flow, this system of vortices has an influence similar to a dipole and produces disturbances only within a short distance. The effect of body thickness, on the other hand, corresponds to a source-sink distribution in the cross section of the body. But in contrast to the source-sink distribution of airfoils, the sum of the source strengths here is not zero. Therefore the effect of the body thickness produces disturbances over a large distance, such as that produced by a pole. Its influence reaches the region outside the validity of incompressible cross sectional flow. For nonlifting bodies, therefore, only the difference between the streams of two bodies with the same total source strength in cross sections can be considered. This difference dies out like a dipole. In this analysis, the same total source strength in all cross sections means the same cross-sectional areas. Bodies of the same cross-sectional area distribution are called "equivalent," and usually the flow properties of a body of low aspect ratio are compared with those of its equivalent body of revolution.

W. D. Hayes (4) made the first theoretical treatment related to the area rule of linear supersonic theory, in which he obtained the wave drag caused by a linear source distribution by integration of momentum over a coaxial cylinder with an integral expression which contains only the source strength. As at large distances it is unimportant whether the sources lie exactly on an axis, as in the case of a body of revolution, or deviate slightly from the axis, the drag integral of Hayes gives the same wave drag for equivalent bodies. This result holds only for bodies with conical or cylindrical ends. Hayes has made no application to equivalent bodies, but his formula for drag is an area integral which corresponds to the well-known drag formula for bodies of revolution in supersonic stream, due to von Kármán.

G. N. Ward (5) made the first definite statement about equivalent bodies. Like Hayes, his findings relate to the supersonic drag in the region of validity of linear theory, whereby the body may also have a lifting force. The drag is calculated by application of Laplace transformations from the momentum of the flow in a transverse plane at the end of the body. His results hold for bodies with arbitrary end shape. Therefore the statements of Ward are valid for bodies with arbitrary cut-off at the ends. Ward says that the drag of a body of low aspect ratio is the same as that of its equivalent body of revolution with conical or cylindrical ends, and he also gives the order of magnitude of the error for this relation. In general there will be one more integral over the end cross section than that in the case of conical or cylindrical ends.

This is important because in practice one seldom has a conical end at the equivalent body of revolution. Ward's estimate of error holds for bodies whose wing span is not greatly different from the diameter of the equivalent body of revolution, and also holds only for moderate supersonic Mach numbers.

Another work on nonlifting bodies of low aspect ratio was published by F. Keune (6) in June 1952. He expanded the double integral formulas for velocity distribution on nonlifting wings for linearized sub- and supersonic theory in terms of small source distance from the axis and obtained two main terms. One is a single integral containing only the distribution of cross-sectional area of the body. It therefore holds for all equivalent bodies. The other main term is a single integral over the source distribution in the cross section considered, fulfilling the Laplace equation in the cross-section plane and therefore representing the cross-section flow. Comparisons with exact calculations show that this method can be widely applied. He also gave the order of magnitude of error of his results.

In Keune's paper very simple formulas for the influence of Mach number in linearized theory are stated, obtained in cooperation with K. Oswatitsch. The influences of Mach number on equivalent bodies are the same, and may be given by the logarithmic additional terms for bodies of revolution which were formerly stated by Oswatitsch. The above results were reported at the International Mechanics Congress in Istanbul (1952) and have been published (8). The formulas for the estimate of errors given in this work have a larger scope of application than those given by G. N. Ward, since they hold for arbitrary thin wings and any Mach number. F. Keune and K. Oswatitsch call the reduction of flow about a wing of small aspect ratio to the flow about the equivalent body of rotation the "law of equivalence." This reduction can be made with single integrals which satisfy the Laplace equation for the cross flow, or with the help of a conformal transformation.

At approximately the same time that F. Keune and K. Oswatitsch worked on this problem, the method of G. N. Ward was extended by M. C. Adams and W. R. Sears (7). The results were reported in America in July 1952 and have been published in J.A.S., 1953. They also analyzed the linear subsonic flow theory with Fourier transformations which were not investigated by G. N. Ward. Not only the drag was calculated but also the whole velocity distribution. Their results contained one more term of the expansion in terms of low aspect ratio than those given by F. Keune (6). The first terms of their expansion are in full agreement, and only in the range where the first expansion term is dominant are there simple relations which can be called "area rule" or "law of equivalence." The next expansion terms obtained by M. C. Adams and W. R. Sears no longer satisfy these simple laws, but their results confirm the estimate of errors given by G. N. Ward and also by F. Keune and K. Oswatitsch. The formula for the drag can also be derived from the velocity distribution either by the momentum integrals (4), (5), (15) or by an integration of the pressure force over the surface of the body (14). Thus one obtains the known expressions for the drag or their extensions to higher order terms.

From the results for pure linear theories in sub- and supersonic stream so far obtained it can be seen that the error for the "area rule" and the "law of equivalence" becomes infinitely large in the hypersonic range (very high Mach numbers) and vanishes at Mach number one. Both can be understood. The range of influence of small disturbances for very high Mach numbers are slender cones lying in the flow direction. One point of the stream field is therefore untouched by the disturbances at another point on the same cross section. Therefore, at very high Mach numbers we can no longer speak about an incompressible cross-sectional flow. It has already been mentioned that the cross-sectional flow is nearly incompressible for a stream with transonic speed. The linearized equation of continuity, which gives a constant mass flow at sonic speed, is the only reason why the discussed theories have been proved to be wholly incompressible in cross planes for Mach number one. The linearization in the Prantl-Glauert analogy for two-dimensional flow gives an infinite air force at Mach number one, and therefore leads to infinitely large error, while the corresponding error is zero in the lifting theory of R. T. Jones (2), "area rule" or "law of equivalence." It should be pointed out that the vanishing error given by the linearized theory at sonic flow is also wrong, because the Mach number is actually different from one in most parts of the transonic flow field. The compressibility of the stream tube depends essentially on the deviations of the Mach number from the value one. The extension of the law of equivalence to the nonlinear range of transonic flow by K. Oswatitsch (9) at the International Mechanics Congress in Istanbul (1952) was based on such thoughts. The error is the smallest in the transonic range. It can be derived from the estimate of errors in the linear theory by introducing a mean value of $(1 - M^2)$, where M is the local Mach number of the sub- or supersonic range at the body, instead of $(1 - M_\infty^2)$. The magnitude of such a mean value at the body can be easily estimated from the disturbances.

K. Oswatitsch and F. Keune gave the estimate of error for the law of equivalence of linear and nonlinear theory in detail in a paper published in 1955 (13). Further results given by these authors may be obtained from *ZAMP* (14). As the incompressible cross-sectional flow does not depend on the Mach number of the stream but only on the form of the body, the law of equivalence can be quoted as follows: "The velocity difference at the same point of the flow field of two equivalent bodies of small aspect ratio is the same for all Mach numbers," or "the influence of compressibility on a wing of low aspect ratio is the same as that of the equivalent body of revolution," etc.

At nearly the same time as the above-mentioned theoretical works were originated, experimental investigations on equivalent bodies in the transonic range were made by R. T. Whitcomb (10), but his report of September 1952 was not published until 1955. This author states that the shock waves in the transonic range become axisymmetrical in a short distance from their starting location, and that they tend to become of the same shape as those of the shock waves of the equivalent body of revolution. These statements were confirmed by his schlieren pictures. Aside from the friction in the boundary layer, the drag of the body can be expressed by the losses in the shocks. The differences in shocks between equivalent bodies are limited to a small portion of the shock surface near the body; hence the drag of equivalent bodies should approximately be the same. Whitcomb made experimental investigations about the accuracy of this rule. After the frictional drag is subtracted, the remaining drag of some of these equivalent bodies is equal, while others with waisted fuselages are not too different. The latter discrepancy may be due to boundary-layer effects. Whitcomb was not so much interested in experimentally finding the relations between equivalent bodies, his main purpose being to find the shape of bodies of low drag. If the drag of a combination of wing and fuselage is to be very small, the equivalent body of revolution must nearly have the smooth form of a low drag body according to Haack-Sears. Thus the area of the fuselage must be reduced in the location of the wings. All wing-body combinations with waisted bodies investigated by Whitcomb show very much smaller drags than those with a cylindrical fuselage. At the Ninth International Congress of Applied Mechanics, G. Drougge (18) (Sweden) showed interesting experiments with two parallel bodies of revolution at sonic

speed. If the distance between the bodies was small enough, the resultant drag of these two bodies was equal to the drag of a single body of revolution, with a cross-sectional area distribution equal to the sum of the areas of the parallel bodies.

In reference (19) D. Küchemann reported on experiments with waisted fuselages made in England during the past few years. This author obtained similar shapes during the Second World War in Germany by forming the surface of the fuselage at the root of a sweptback wing according to the streamlines of an infinite sweptback wing.

After this survey of theoretical and experimental work in the transonic range, we now go back to discuss some recent progress of the linear theory of supersonic flow. The early work of Hayes (4) was further developed by R. T. Jones (11) and G. N. Ward (12), such that exact formulas for the drag of bodies of arbitrary shape were given. The American results have also been treated in other papers (16), (17). According to these, the supersonic drag for bodies of arbitrary shape can be obtained from the area of a tangential plane of the Mach cone which cuts the body considered, but not from the cross-sectional area of the body only. Each position of the tangential plane gives a certain cross-sectional area. The drag formula should be applied to all of those sectional planes and the results should be averaged. This new drag formula, at low supersonic Mach number, tends to be the old drag formula of G. N. Ward. This is due to the fact that at low supersonic Mach number the Mach angle tends to be 90°. It should be noted that this result is not valid for the transonic stream because of the linearized differential equations. The drag is calculated by pure area integrals which contain both the double integration in the flow direction of the von Kármán body of revolution, and another average integral in all the different directions of the tangential planes.

The theories and rules talked about are generally restricted by additional assumptions. It has already been said that the equivalent bodies of revolution must be with pointed tip, and often with conical or cylindrical ends. Usually it is forbidden to have a discontinuity in the wings. The trailing edges of the wings in subsonic flow must be a cusp. The fulfillment of these requirements in practice has been discussed in certain literature which we shall not mention here. In spite of these restrictions, which require attention when applying these laws to bodies of low aspect ratio and when using the integrals of supersonic drag, the theories have been proved to be very useful.

Usually a paper begins with an exact explanation of the title. However in the present case, such a definition has not been given because there are at least three different definitions of "area rule" (e.g., see ref. 20). The following definitions are not ordered historically.

In literature, the "area rule" is stated as:

(a) The reduction of the flow around a body of low aspect ratio in a linearized flow field or in the transonic flow field to that of an equivalent body of revolution, especially the reduction of the drag to that of the equivalent body.

References (5), (6), (7), (8), (9), (13), (14), (15), (18) and partly (10) deal with this problem. The term "law of equivalence" is used by some authors for this reduction.

(b) Rules about shapes of body of low drag, particularly in the transonic range as well as in the supersonic stream.

A quotation of such works must begin with reference (3). References (18) and (19) deal wholly, and references (10), (16) and (17) deal partly, with this problem. In the transonic range the area rule affords instruction as to the best shape of the fuselage. The minimum drag problem in linearized theory has been treated in a great number of papers, starting with the Busemann biplane.

(c) The analysis of supersonic drag as integrals over sectional areas of body without restriction to small aspect ratio.

References (4), (11), (12), (16) and (17) deal with this question. For example, in reference (16) a "supersonic area rule" in connection with the threefold integral for supersonic drag has been explicitly mentioned.

If the question of who was the founder of the "area rule" is asked, an exact definition of the rule must be given. This paper gives, therefore, a survey of all the works that can be connected with the title. Furthermore, the references may not be complete because some of the papers are classified or are contained in proprietary industrial research which can hardly be obtained. Some additional literature may be found in the references.

The author acknowledges the help of Professor Shih-I Pai for the English version.

REFERENCES

1 Munk, M. M., The aerodynamic forces on airship hulls, *NACA Rep.* 184, 1924.

2 Jones, R. T., Properties of low-aspect-ratio pointed wings at speeds below and above the speed of sound, *NACA Rep.* 834, 1946.

3 Frenzl, O., Motorgondel-Flugel-Interferenz bei hohen Geschwindigkeiten (Die Flachenregel), *Z. Flugwiss.* 5/6, 1957.

4 Hayes, W. D., Linearized supersonic flow, *No. Amer. Aviat. Rep.* AL-222, June 1947.

5 Ward, G. N., Supersonic flow past slender pointed bodies, *Quart. J. Mech. appl. Math.* **2**, 1, Mar. 1949.

6 Keune, F., Low-aspect-ratio wings with small thickness at zero lift in subsonic and supersonic flow, *Kungl. Techn. Hogsb., Stockholm, KTH-AERO TN* 21, June 1952; AMR **6**, Rev. 3508.

7 Adams, M. C., and Sears, W. R., Slender-body theory—review and extension, *J. aero. Sci.* **20**, 2, 1953; AMR **6**, Rev. 3136.

8 Keune, F., and Oswatitsch, K., Nicht angestellte Koerper kleiner Spannweite in Unterund Uberschallstroemung, Eighth International Congress Theor. and Appl. Mech. Aug. 1952. Oder ausführlich: *Z. Flugwiss.* **1**, 6, Nov. 1953; AMR **8**, Rev. 1097.

9 Oswatitsch, K., Die theoretischen Arbeiten über schallnahe Strömung am Flugtechnischen Institut der Königl. Techn. Hochsch., Stockholm, Eighth International Congress Theor. and Appl. Mech. Aug. 1952.

10 Whitcomb, R. T., A study of zero-lift drag-rise characteristics of wing-body combinations near the speed of sound, *NACA RM* L52 HO8, Sept. 1952; or: NACA details area rule break-through, *Aviation Week* Sept. 1955; AMR **10**, Rev. 3690.

11 Jones, R. T., Theory of wing-body drag at supersonic speeds, *NACA RM* A53 H18a, 1953.

12 Ward, G. N., The drag of source distributions in linearized supersonic flow, *Coll. Aero. Cranfield Rep.* **88**, 1955; AMR **8**, Rev. 3111.

13 Oswatitsch, K., and Keune, F., A theorem of equivalence for wings of small aspect ratio at zero incidence in transonic flow (in German), Roy. Aircr. Estab., Library Transl. 545, Aug. 1955; AMR **8**, Rev. 3821.

14 Keune, F., and Oswatitsch, K., Aequivalenzsatz, Aehnlichkeitssatze fur schallnahe Geschwindigkeiten und Widerstand nicht angestellter Koerper kleiner Spannweite, *ZAMP* **7**, 1, 1956; AMR **9**, Rev. 3988.

15 Berndt, S. B., On the drag of slender bodies at sonic speed, *Flygtekn. Foersoeksanst. Medd.* 70, 1956; AMR **10**, Rev. 3691.

16 Lomax, H., and Heaslet, M. A., Recent developments in the theory of wing-body wave drag, *J. aero. Sci.* **23**, 12, 1956.

17 Jones, R. T., Theory of wing-body drag at supersonic speeds, *NACA Rep. 1284*, 1956.

18 Drougge, G., Some measurements on bodies of revolution at transonic speeds, Ninth International Congress of Appl. Mech., Brussels, 1956.

19 Küchemann, D., Methods of reducing the transonic drag of sweptback wings at zero lift, *J. roy. aero. Soc.* Jan. 1957; AMR **10**, Rev. 1843.

20 Keune, F., Zusammenfassende Darstellung und Erweiterung des Aequivalenzsatzes fur schallnahe Stroemung, *Dtsch. Versuchsanstalt Luftfahrt E.V.* **8**, 1956; AMR **10**, Rev. 2190.

"Letters to the Editor" and "Books Received for Review" now appear after the reviews.

Theoretical and Experimental Methods

(See also Revs. 3899, 3900, 3901, 3904, 3907, 3908, 3911, 3912, 3941, 3947, 3956, 3957, 3966, 3970, 3983, 4001, 4003 4023, 4024, 4030, 4090, 4113, 4114, 4132, 4156, 4165, 4174, 4175)

Book—3878. Budak, B. M., Samarskii, A. A., and Tikhonov, A. N., Collection of problems in mathematical physics (in Russian), Moscow, Gos. Izdat. Tekh. Teor. Lit., 1956, 683 pp. 14 r. 45 k.

It is very difficult to find, in the world literature, any work of this kind comparable with the title book. Engineers, applied mathematicians, and physicists will find in this excellent compilation of 855 selected problems an inexhaustible source for gaining the highest degree of routine in solving the most important questions from all branches of mathematical physics. A serious study and conscientious calculation of problems involved suggests to everyone innumerable original ideas and leads inevitably to successful self-reliant work in this fundamental branch of modern science.

The book originates in several years' courses of mathematical physics given at the physical faculty of the Moscow University. The text consists of two main parts, the first of which gives descriptive and physical or mathematical statement of separate problems, the second supplies methodical hints and complete solutions. Volume concludes with a fine appendix on various systems of rectangular coordinates, on special functions, and with numerical tables.

First of all comes a short introductory chapter with 29 examples for reducing equations of two and more independent variables to canonic form. Chapter II deals with hyperbolic equations when belonging physical processes can be characterized by one space and one time coordinate. There are 202 problems of this kind. Following main part has for subject parabolic equations with two independent variables; it contains 117 selected problems from various fields of engineering and theoretical physics. Chapter IV is devoted to simpler elliptic problems, primarily to those characterized by the Laplace equation. Altogether 171 questions are formulated and solved in this section. Chapter V brings 101 problems on parabolic equations with three and four independent variables. The sixth main part contains 127 hyperbolic equations and problems with more independent variables and presents a continuation of Chapter II. Finally come 108 selected questions relating to the Helmholtz equation.

The study assumes an adequate knowledge of the discipline, about to the extent as the well-known work by Tikhonov and Samarskii [AMR **5**, Rev. 2249]. Naturally, the book does not apply all methods current in mathematical physics; for instance, integral equations, variational and operational methods are not treated. Volume ends with a list of 47 literary sources.

The extraordinary significance of the above work is evident. Such a book does not need any recommendation.

V. Yodicka, Czechoslovakia

Book—3879. Gröbner, W., Matrix calculation [Matrizenrechnung], München, Verlag von R. Oldenbourg, 1956, 249 pp.

Professor Gröbner of the University of Innsbruck gives a comprehensive treatment and clear exposition of matrix theory. Book is better suited probably as a text to his lectures than for use as either a reference book or for purposes of private studies. The many exercises and well-selected problems are more helpful to the mathematically inclined reader than to the physicist or research engineer. This comment applies to the entire book since it does not mention any of the numerous well-known technical applications of matrix theory. (The chapter on the method of least squares, written with commendable clarity, is the only one vaguely connected with immediate technical applications.)

Author's prerequisites are knowledge of fundamentals of algebra, of algebraic equations and operations. To this list this reviewer would like to add the requirement of an unusual amount (as far as engineers are concerned) of interest and patience toward pure mathematics.

Treatment of determinants (via Grassmann's outer product of vectors), discussion of linear algebra, and the many geometrical references make reading an enjoyable experience.

Book compares favorably with classics (e.g. MacDuffee's book), but among readers interested mainly in applications, Gröbner's book will have limited popularity and will take probably second preference to Duschek's contribution [AMR **9**, Rev. 1331].

V. G. Szebehely, USA

3880. Kosko, E., Matrix inversion by partitioning, *Aero. Quart.* **8**, part 2, 157–184, May 1957.

Paper discusses at some length advantages of partitioning for inverting matrices. Super-matrix is matrix whose elements are themselves matrices, and main attention is given to super-matrices of orders two and three, and to economic methods of carrying out the computation. Advantages are also claimed for super-matrices of any order of continuant and circulant type, or with special kinds of symmetry. A tabular summary of counts of multiplications, compared with those for elimination, supports this claim. All submatrices or auxiliary matrices which have to be inverted are assumed nonsingular. Reviewer suggests this may be a disadvantage, since, in practice, singularity or near singularity of such matrices is not uncommon.

L. Fox, England

3881. Guest, J., The determination of matrix eigenvalues by the Hollerith computer, *Aero. Res. Lab., Melbourne, Austral. Notes* SM 233, 6 pp. + 3 figs., Aug. 1956.

3882. Wilson, E. M., A family of integrals occurring in the theory of water waves, *Quart. J. Mech. appl. Math.* **10**, part 2, 245–253, May 1957.

Author studies the integral $\int_0^{\pi/2} (e^{-\alpha^2 \sec^2\theta + i\beta\sec\theta}) \sec^n\theta d\theta$ and derives numerous expressions to facilitate its computation.

Y. L. Luke, USA

3883. Bakhvalov, N. S., Numerical integration of differential equations by the method of finite differences (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **104**, 6, 805–808, Oct. 1955.

3884. Fox, L., Boundary-value techniques for the numerical solution of initial-value problems in ordinary differential equations, *Quart. J. Mech. appl. Math.* **10**, part 2, 232–243, May 1957.

It is known that initial-value problems can be transformed into higher-order systems, and the latter treated either as initial-value problems or as boundary-value problems. Solution is by finite difference methods and the question of stability is all important. Paper considers in detail the advantages and disadvantages of each transformation. Some numerical examples are presented.

Y. L. Luke, USA

3885. Eidus, D. M., Boundary-value problem for the equation $\Delta u + \lambda^2 u = 0$ (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **100**, 4, 631–633, 1955.

3886. Kreyzig, E., On certain partial differential equations and their singularities, *J. rational Mech. Analysis* **5**, 5, 805–820, 1956.

Book—3887. Johnstone, R. E., and Thring, M. W., Pilot plants, models, and scale-up methods in chemical engineering, New York, McGraw-Hill Book Co., Inc., 1957, xi + 307 pp. $9.50.

This well-organized and well-printed book is the first text on dimensional analysis and related subjects specifically directed to chemical engineers. The first nine chapters (111 pages) are devoted to general definitions, concepts, techniques, and limitations. Included is a discussion of all types of similarity: geometric, static, kinematic, dynamic, thermal, and chemical. Various techniques for forming dimensionless groups are discussed and exemplified by analysis of the fundamental equations of flow, transfer, and reaction. The latter covers the fundamental work of Damköhler, usually overlooked in other books on this subject. Practical features of applying dimensional analysis, including extrapolation and boundary effects, are also discussed. The following nine chapters (137 pages) are devoted to examples taken from various chemical engineering problems: flow through ducts, filtration, heat transfer, packed towers, mixing equipment, chemical reactors, furnaces and kilns, miscellaneous equipment, and corrosion. A last chapter (28 pages) is devoted to a brief but adequate discussion of analogs. The appendices include a valuable glossary of terms relating to model theory, a useful table of dimensions of various physical and chemical quantities, a partial listing of dimensionless groups, and a note on automatic control.

Reviewer feels book is most successful in its general treatment of dimensions, similarity, etc. Authors have recognized both the engineer's need for broad application of dimensional methods and his practical approach to them. For example, all systems of units are considered, the more commonly used "engineering" systems as well as the "consistent" units preferred by physicists and chemists. Unfortunately, some inconsistencies appear in applying these systems. In discussing flow through ducts, authors use for the Newton's law conversion factor, g_c, the same symbol (g) used elsewhere in the chapter for acceleration of gravity. In the appendix, some of the dimensionless numbers listed are in the six-dimension engineering system, and others in the four-dimension consistent system; for example, the Euler number includes the factor g_c, while the Weber number does not. Since this whole problem is confusing to many readers, authors should have been more careful to eliminate inconsistencies in their treatment.

More serious is the authors' inability to limit themselves to purely dimensional considerations; they wander off into many statements concerning general principles of operation, especially in chapters devoted to examples of application. Since these examples comprise practically all of chemical engineering, and their treatment is necessarily brief, the result is a rather naive picture of the various items discussed. As an example, in deriving the Weber number, authors state that "the general mechanism of dispersion" of one liquid in another is due to centrifugal force, resulting from spinning of globules! Reviewer would hesitate to say that such forces do not act, but could list many others which are probably more effective in causing dispersion. Where the authors are experts in the field, as in the discussion of furnaces and kilns, their treatment is quite adequate, but in other chapters it is definitely unsatisfactory, since it leaves an impression that the operation is much simpler than it really is. The book should either be limited to strictly dimensional problems, by relying on the reader for background understanding of any examples used, or expanded into a general treatment of the entire field of chemical engineering.

In spite of these drawbacks, reviewer recommends this book as the best available text for chemical engineers. Mechanical engineers, especially fluid dynamicists, probably prefer the specialized treatment of Langhaar [AMR **4**, Rev. 4042]; physicists may prefer the more rigorous treatment of Duncan [AMR **7**, Rev. 1692], or the philosophical excursions of Focken [AMR **7**, Rev. 2734]; but chemical engineers need a broader type of treatment exemplified in the present text. It is only to be hoped that later editions will eliminate some of the present drawbacks.

R. R. Hughes, USA

3888. Yakub, B. M., One direction in similarity theory (in Russian), *Tekhnika Zh. D.* no. 2, 15–17, 1953; *Ref. Zh. Mekh.* 1956, Rev. 4139.

Critical notes are supplied on P. K. Konikov's book ["On the similarity theory and its application to steam pipe engineering," Moscow, Mashgiz, 1951]. Author cites examples of mathematical and mechanical errors found in the book. In particular, he dwells on the similarity theory expounded by Konikov, which is intended to be the most fundamental part of the book, and examples are quoted of serious errors. G. I. Barenblatt, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3889. Cumming, I. G., Some statistical observation on the estimation of fibre strength, *J. Text. Inst. Trans.* **48**, 5, 143–153, May 1957.

Author considers relation between mean strength (average of breaking load L per unit cross-sectional area ~ square of diameter d; i.e., $\langle L/d^2 \rangle$) and an approximation to it, $\langle L \rangle / \langle d \rangle^2$, for a group of textile fibers for which $\langle L \rangle$, $\langle d \rangle$, σ_L, σ_d, and ρ_{Ld} are known. The results are compared with some experimental findings on Ardil, wool, nylon, and flax. For fibers of not unduly irregular cross section, the more easily determined quantity $\langle L \rangle / \langle d \rangle^2$ is at worst a few per cent smaller than the accurately calculated quantity $\langle L/d^2 \rangle$. In most practical cases, this error in approximating the mean strength of the sample is small compared with the sampling error in estimating the mean strength of the lot. Regrettably, the paper is marred by unfortunate notation and exposition, and by some errors unimportant for the immediate purpose of the paper. D. J. Montgomery, USA

3890. Fractional factorial experiment designs for factors at two levels, *Nat. Bur. Stands. AMS* no. 48, 85 pp., Apr. 1957.

When it is necessary to evaluate the joint effect of several factors, factorial designs of experiment have particular value [see feature article AMR **8**, Oct., 1955, page 405, "Essence of design of experiments"]. This catalog of such designs is a useful compilation. The factors are all taken at two levels.

To enable the number of tests to be kept within reasonable limits, fractional replicate designs are proposed. Fractions of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, $\frac{1}{128}$, and $\frac{1}{256}$ for from 5 to 16 factors are tabulated. It is suggested that the designs may also be useful when it is desired to conduct a sequence of smaller experiments, each then being a fractional replicate. When it is desired to find an optimum condition for the number of factors simultaneously, reviewer suggests that reference should also be made to the work of G. P. Box ["Design and analysis of industrial experiments," edited by O. L. Davies, Oliver and Boyd, 1954, chap. 11].

R. L. Brown, England

3891. Longuet-Higgins, M. S., The statistical analysis of a random moving surface, *Phil. Trans. roy. Soc. Lond. (A)* **249**, 966, 321–387, Feb. 1957.

Subject is treated as a branch of geometry by author. He states that, while this analysis may be used to study ocean waves, ionospheric perturbations, and microseisms, application of the results will be given in a later study. The following are derived for a random moving Gaussian surface: (1) *probability distribution* for (a) surface elevation, (b) magnitude and orientation of gradient, (c) velocities of zero crossings along a given line, (d) velocities of contours and specular points, (e) envelope and phase angle, (f) narrow spectrum heights of maxima and minima; and (2) *average* for (a) length of contours per unit area of surface, (b) density of specular points. Results are given in terms of two-dimensional energy spectrum of surface. Article is mathematical and makes use of matrices and transform calculus. Author begins arguments with elementary concepts so that development is readily followed. Paper has 37 references, including 19 recent ones on statistical analysis of ocean waves. R. C. Staley, USA

3892. Wilcoxon, F. W., Experimental design in industry, *Indust. Lab.* **7,** 8, 5–8, Aug. 1956.

3893. Bellman, R., On a class of variational problems, *Quart. appl. Math.* **14,** 4, 353–359, Jan. 1957.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 3921, 3924, 3935, 3936, 3953, 3955, 4027, 4114, 4216, 4217, 4218, 4223)

Book—3894. Peach, M. O., A modern course in engineering statics (Univ. Notre Dame, Canada), Montreal, Renouf Publishing Co., Ltd., 1956, viii + 31 Lessons.

Author presents four basic tools of statics in the form of four rules, three of them being applicable to all material systems and the fourth only to rigid bodies. Principle of transmissibility of force has been discarded, as one has to do in analysis of strength of materials, elasticity, and other continuum mechanics. Emphasis is laid on the construction of free body diagrams from the beginning. There are abundant worked examples and they are excellently set and easy to follow. The methods of statics are extended to broad class of nonequilibrium bodies by the aid of D'Alembert's principle. Use has been made of vector algebra. Author also gives a concept of stresses in elastic material as a second-order tensor. In reviewer's opinion, the book will be helpful in understanding fundamental principles of mechanics.

D. N. Mitra, India

3895. De Smedt, J., and De Bock, A., Horizontal pendulum with variable modulus of torsion (resonance curve), *Amer. J. Phys.* **25,** 3, 155–156, Mar. 1957.

A didactical apparatus for accurate determination of resonance curves is presented. A bifilarly suspended disk, whose natural period is variable between large limits while the system is oscillating, is suited for easy determination of a resonance curve, because the period of the forced oscillation can remain unchanged during operation. The rigidity and hence the natural period of the pendulum is altered by a change in the mass supported by the bifilar suspension; this is done by means of a third axial wire, from the disk to a yoke carrying counterweights.

From authors' summary

3896. Federhofer, K., Kinematics of the sliding curved-link mechanism (in German), *Öst. Akad. Wiss. Math.-nat. Kl. S. B. (IIa)* **164,** 10, 473–482, Aug. 1955.

This mechanism is basically a single-edge cam with a curved follower which is rotating about a fixed point. (The two members can be exchanged, i.e., the follower can be the cam, and vice versa.) The system can be regarded as a four-link mechanism by using the sum of the two radii of curvature (constant for two time elements) to the point of contact as a link. Author is then able to determine the radii of curvature of the two paths of contact in relation to the cam and the follower.

C. B. Ludwig, USA

3897. Paslay, P. R., and Slibar, A., The motion of automobiles on unbanked curves, *Ing.-Arch.* **24,** 6, 412–424, 1956.

The motion of an automobile in a curve has been treated both experimentally and theoretically by various authors; their analyses have shown the complexity of the problem and its many close relations to other problems in automotive engineering. For many problems connected with the motion of an automobile in a curve the complete solutions are still unknown. Two such problems are the behavior of tires and the response of an automobile going over a bump. In spite of the lack of information in so many related fields, the treatment given here shows that for driving through an unbanked curve theoretical results which check existing experimental results can be obtained by an approximate theory by making use of previous experimental work.

From authors' summary

3898. Signorini, A., Recent research in dynamics of solids (in Italian), Proceedings, Eighth international Congress on theoretical and applied Mechanics, Istanbul, Turkey, Aug. 20–28, 1952; Vol. II, Part IV–General lectures and sectional addresses, pp. 129–135. Istanbul, Faculty of Science of the Univ. of Istanbul, 1955.

3899. Fayard, G., Application of harmonic analysis for the calculation of some geometric characteristics of contour planes (in French), *Rech. aéro.* no. 52, 37–40, July/Aug. 1956.

Derivation of formulas for the center of gravity, etc., if the contours are represented by $X = X_0 \sin \alpha$, $Y = \sum_0^n (a_n \cos n\alpha + b_n \sin n\alpha)$ and a_n, b_n are determined by least squares.

H. Witting, Germany

Servomechanisms, Governors, Gyroscopics

(See also Revs. 4112, 4143, 4174)

Book—3900. Grabbe, E. M., edited by, Automation in business and industry, New York, John Wiley and Sons, Inc., 1957, xix + 611 pp. $10.

Book is a compilation of a lecture series given at the University of California. In such series, individual lecturers do not know in advance the contents of other lectures and thus material is nonuniform in aim and requirements. Large parts are descriptive, nonmathematical, and yet not readily understandable to the nonspecialist, because of a lack of explanation of terms. Other parts go into considerable detail of electronic and mathematical performance and require for understanding more background than the average engineer will bring along. While a book on automation which would introduce this field to engineers and physicists not active in it would be highly desirable, this book cannot satisfy this need.

Several authors review what might be called a philosophy of automation but do not come to grips with the basic fact that automation is introduced only if and when more production per man hour is achievable than without it. The social problem of what to do with the man hours so saved is not discussed, but hidden in the trivial statement that the process of automation will come slowly anyhow and that technological progress "in the long run" never has lead to unemployment. Does mankind gain by more gadgets? Can automation reduce the most urgent need of mankind: food, shelter and clothing for the less developed part of the world? Is man ready to wisely use increased leisure, promised by automation? These questions, pertinent to the "philosophy of automation," are not even raised, let alone answered, in this book.

V. Paschkis, USA

3901. Ludeke, C. A., Nonlinear phenomena, *Trans. ASME* **79,** 3, 439–444, Apr. 1957.

Paper describes observed phenomena in nonlinear systems. These include: variation of the amplitude of forced oscillations with the exciting frequency; the so-called "jump phenomenon" under forced conditions where a sudden transition occurs from the fundamental or a subharmonic mode of response to a different mode; conditions of nonlinear self-sustained oscillations and limit cycles; and the phenomenon of frequency entrainment associated with beats. Paper describes observations based upon analog studies and emphasizes deviation from performance characteristics of linear systems. It does not explain results through mathematical

analysis but proposes such analysis as a worthwhile subject of further research. Reviewer concurs that subject is of practical significance, particularly in the fields of mechanical vibration and feedback control.

Discussors raise question of considerable significance concerning observations made by author of even-order subharmonic response in a system subject only to odd-function type of nonlinearity. One discussor (Chihiro Hayashi, Cambridge, Mass.) considers this possible and based upon a self-biasing property of the system. Other discussor (Karl Klotter, Stanford, Calif.) questions observation and attributes it to existence of other even-order nonlinear effects unintentionally introduced in the analog model. Resolution of this question would be of practical interest.

Reviewer suggests that many of phenomena observed could be explained by the describing function approach; the higher-harmonic generation ability of nonlinear elements appearing in a feedback path can explain the production of subharmonics in the complete system. Use of electronic, rather than mechanical, analogs is also suggested to avoid unintended secondary effects such as those suggested by one discussor (Dr. Klotter). In any event, paper poses a significant problem worthy of considerable further research.

R. Kochenburger, USA

3902. Shen, C. N., Miller, H. A., and Nichols, N. B., Nonlinear integral compensation of a velocity-lag servomechanism with backlash, *Trans. ASME* **79,** 3, 585–592, Apr. 1957.

The loop gain of a simple velocity-lag servomechanism is generally very large and is limited only by the requirement for adequate damping. However, the presence of backlash imposes additional and severe limitations on the allowable gain if stability is to be maintained. As a result, the following error for steep ramp inputs may be excessive. Integral compensation normally is used to increase the loop gain, but the presence of backlash can result in oscillations. Authors offer solution to this problem consisting of incorporating dead zone in the input to the integrator. Convenient means are given for approximating transient response of resulting system. A disadvantage that accrues from this method of compensation is a steady-state offset at the output. Possible means of reducing this offset are discussed.

S. Z. Dushkes, USA

3903. Higgins, T. J., A resume of the development and literature of nonlinear control-system theory, *Trans. ASME* **79,** 3, 445–453, Apr. 1957.

Paper presents an historical description and supporting bibliography of the development of methods for analyzing nonlinear systems and predicting their performance characteristics. Accent is on those of particular application to nonlinear feedback control systems. Author points out that considerable early work, some dating back to eighteenth and nineteenth centuries, has been "rediscovered" more recently by engineers working in this field. He mentions the more basic historical contributions and proposes a thirty-four item bibliography as basic reading for the engineer interested in this field.

Comments by thirteen discussors are also of interest and treat various padagogical and philosophical problems that arise. Two viewpoints are apparent: One is that of the scientist interested in a rigid and complete, although possibly lengthy, treatment. The other is that of the engineer interested in a ready working solution to a specific problem. A comment by one discussor (G. J. Murphy, Minneapolis, Minn.) presents one viewpoint different from that of the author and refers to the dilemma of the engineer who requires a knowledge of working techniques of nonlinear system analysis but who lacks the time to devote to even a bibliography of the scope proposed by the author. Reviewer suggests that it would appear to be the responsibility of teachers and technical authors to combine and abstract such basic material, and to present it in a form employing consistent engineering nomenclature so that it would become more readily available to the practicing engineer.

E. Kochenburger, USA

3904. Merson, R. H., A generalisation of the Nyquist stability criterion with particular reference to phasing error, *Aero. Res. Counc. Lond. curr. Pap.* 330, 8 pp. + 1 fig., 1957.

Nyquist stability criterion is applied to a two-dimensional linear system, such as a tracking radar, containing two identical servos coupled by a resolving or phasing error. It is shown that stable system will result if phasing error is less than phase margin in absence of phasing error.

Nyquist criterion is also formulated for general case of multidimensional linear systems containing identical coupled servos.

L. Becker, USA

3905. Gopp, Yu. A., A new solution of J. A. Vyshnegradsky's problem in the theory of positive governing (in Russian), *Trudi sem. teor. Mash. Mekh. in-ta mashinoved. Akad. Nauk SSSR* **14,** 55, 63–70, 1954; *Ref. Zh. Mekh.* 1956, Rev. 3398.

For a system for the positive governing of a first-order object without self-stabilization, a Vyshengradsky diagram is constructed with the coordinates

$$v = \frac{T_r^2}{\delta^3 T_a^2}, \quad u = \frac{T_k}{\delta^2 T_a}$$

termed by the author the "natural" coordinates.

The region of the parameters in which the transitional process is oscillatory without overdriving is isolated. The parameters are selected, defining the degree of stability of the system attainable as the maximum for the particular object having regard to the real possibilities of constructing the sensitive element of the governor.

Courtesy Referativnyi Zhurnal R. A. Poluektov, USSR
Translation, courtesy Ministry of Supply, England

3906. Gopp, Yu. A., Analysis of a degenerated system of derived controls by means of a detailed Vyshnegradsky diagram (in Russian), *Trudi sem. teor. Mash. Mekh. in-ta mashinoved. Akad. Nauk SSSR* **14,** 55, 71–78, 1954; *Ref. Zh. Mekh.* 1956, Rev. 3399.

For a degenerated system of derived control ($T_r = 0$) of a first-order object without self-stabilization, a Vyshnegradsky diagram is constructed with the coordinates

$$s = T_s/\delta T_a \text{ and } k = T_k/\delta^2 T_a.$$

Lines of equal values of the real root and lines of equal values of the real parts of the complex-conjugate roots of the characteristic equation are plotted on the diagram.

It is demonstrated from analysis of the detailed diagram that in the system under consideration the transitional process may either be aperiodic or oscillatory with over-governing. To facilitate the problem of synthesis of the degenerated system of derived control, the relationships are plotted between the real part of the minimum root of the standardized characteristic equation and the magnitude of the parameter s at varying values of the parameter k.

Courtesy Referativnyi Zhurnal R. A. Poluektov, USSR
Translation, courtesy Ministry of Supply, England

3907. Looney, R., Method for presenting the response of temperature-measuring systems, ASME Ann. Meet., New York, N. Y., Nov. 1956, Pap. 56-A-102, 5 pp.

Paper supplements companion by Coon [see following review] and considers the application of that method to gas- and mercury-filled tube systems used as temperature-sensing elements. Schemes are proposed for determining relation of element design constants to value of single time constant employed in the response representation. This time constant is expressed in terms of the equivalent single-order system presenting the same steady-

state response lag to a ramp (constant-rate temperature change) input. A graphical method of time-constant evaluation and the application of the method to experimental as well as design constant data are proposed. Practical applications of the method are the same as those of the companion paper by Coon. In general, method is applicable when the temperature-sensing element does not represent the principle lag of the process. Otherwise, as stated by the author, a more complete analysis would be required.
R. Kochenburger, USA

3908. Coon, G. A., Responses of temperature-sensing-element analogs, ASME Ann. Meet., New York, N. Y., Nov. 1956, Pap. 56-A-101, 9 pp.

Paper discusses simplified analytic representations of temperature-sensing elements for purpose of determining control-system stability. The proposed method is considered permissible because response of element is significant only in lower frequency range where the controlled system phase lags are less than 180 deg. Consequently, representation of sensing elements in terms of a single-order exponential type of response lag appears adequate even though the actual dynamics are more complex.

Subject treated is of practical importance in field of temperature control. Method is described in terms of analogous electrical circuits. Although not explicitly stated by author, the sensing elements being considered are, in the strict sense, of a distributed- rather than lumped-parameter nature. Approximation proposed by author is similar to the simplifying lumped-parameter approximations made by electrical engineers in the representation of transmission lines. Proposed approximation is of practical utility in that it will simplify the analysis of many thermal control systems. Paper includes mathematical justification of the treatment and also includes an extensive mathematical derivation in an appendix.
R. Kochenburger, USA

3909. Nightingale, J. M., Some design considerations for a hydraulic servo, *Aircr. Engng.* **28,** 330, 254–259, Aug. 1956.

3910. Heintz, R. P., Minimizing undesirable oscillations in certain two-state electrohydraulic control valves, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-158c, 6 pp.

Vibrations, Balancing

(See also Revs. 3926, 4212, 4241)

Book—3911. Cole, E. B., Theory of vibrations for engineers, New York, The Macmillan Co., 1957, xiv + 362 pp. $6.

Author, who has taught dynamics several years at the University of Liverpool, presents now the third edition of his book, which will bridge the gap between the elementary treatment and the important analysis available for problems of modern high-speed machinery. For the solution of simple harmonic forced vibrations the vector method is preferred in a manner similar to electrical current problems, but no complex variables are used. In the new edition, the book contains a very great number of excellent examples which are well illustrated and give good information to the learning student as well as to the practical engineer.
H. Neuber, Germany

3912. Atkinson, C. P., Electronic analog computer solution of nonlinear vibratory systems of two degrees of freedom, *J. appl. Mech.* **23,** 4, 629–634, Dec. 1956.

Paper reports on a series of analog computer runs dealing with the response to a sinusoidal driving force of two coupled undamped oscillators with cubic restoring or coupling force. Purpose of the runs is a check on earlier [AMR **9,** Rev. 2446] analytical work on the same system, using Ritz-Galerkin's method. Discrepancies are noted between the two approaches and tentatively diagnosed.

Stability criteria are speculated upon. R. Drenick, USA

3913. Popov, E. P., A generalization of the asymptotic method of N. N. Bogoliuboff in the theory of nonlinear oscillations (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **111,** 308–311, 1956.

The differential equation

$$\ddot{x} + 2b\dot{x} + c^2x = \epsilon f(x, \dot{x}),$$

where bc, ϵ are positive constants (ϵ small) and f is nonlinear is nonlinear, is subjected to the Bogoliuboff general method [Bogoliuboff-Mitropolski, "Asymptotic methods in the theory of nonlinear oscillations, chap. 1]. This method was applied in that book to the case $b = 0$. Let $\omega = c^2 - b^2)^{1/2}$. A solution is assumed of the form

$$x = a\cos\psi + \epsilon\varphi_1(a, \psi) + \dots,$$

with

$$\dot{a} = -ba + \epsilon\Phi_1(a) + \dots,$$

$$\dot{\psi} = \omega + \epsilon B_1(a) + \dots,$$

the series being taken merely "formally" and used à la Bogoliuboff only to find approximate solutions mod ϵ^m. [Additional references: Bogoliuboff, *Sbornik trudov Inst. Stroitel' moi mehan. Akad. Nauk USSR* **10,** 9, Kiev, 1949; Grensted, *Proc. IRE* **102,** part B5, 1955 (English); Popov, *Izv. Akad. Nauk SSSR, Odel tekh. Nauk* no. 9, 1956]. S. Lefschetz, Mexico

3914. Pell, W. H., Graphical solution of single-degree-of-freedom vibration problem with arbitrary damping and restoring forces, *J. appl. Mech.* **24,** 2, 311–312, June 1957.

Paper presents a slight generalization of the graphical method of Lienard for autonomous nonlinear systems in which the displacement and velocity functions are distinct. Two examples are given. H. N. Abramson, USA

3915. Feldman, M. R., The steadiness of the oscillations of bars and plates of time-variable mechanical properties (in Russian), *Sb. nauch. tr. Leningr. inzh.-stroit. in-ta* no. 1/2, 200–209, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4670.

The discussion is based on the classic linear theory of creep, the nuclei being introduced in exponential form. In such cases the equations of oscillation of bars and plates can be reduced to the form of linear differential equations. The boundary conditions selected (for the bar, hinge-supported at the ends; for the plate, hinge-supported on all edges and uniform compression in two directions) enable the variables to be divided. Applying the usual criterion of steady oscillation, author finds for the active loads the following expression for the case of the bar:

$$p < p_e(1 - \chi/\lambda)$$

in which p_e = the critical Euler force, λ = the Lamey coefficient, and χ is the relationship of the elastic and viscous forces in the material. For the case of the plate, assuming the material to be isotropic, we have

$$p_1\frac{m^2}{a^2} + p_2\frac{n^2}{b^2} < D\pi^2\left[\frac{m^2}{a^2} + \frac{n^2}{b^2}\right]^2\left(1 - \frac{\chi}{\alpha}\right)$$

in which α is the characteristic of the viscous properties of the material, D is the cylindrical rigidity, m and n are the half waves along the lengths a and b, p_1 and p_2 are the corresponding forces on the edges $x = 0$, $x = a$ and $y = 0$, $y = b$.

Courtesy Referativnyi Zhurnal S. A. Shesterikov, USSR
Translation, Courtesy Ministry of Supply, England

3916. Keller, W., New critical speeds of a rotating shaft with one disk (in German), *Ing.-Arch.* **25,** 2, 71–89, 1957.

This is a comprehensive and profound theoretical study of critical speeds of a rotating shaft with one concentrated somewhat

eccentric disk. Shaft is loaded by constant and pulsating axial force and torsional moment. Gyroscopic effects are excluded. Influence coefficients are computed by successive approximation. Equations of motion are of Hill's type, which are simplified into Mathieu equations. Axial force and torsional moment, with frequency simply related to rotational speed, introduce an infinite number of secondary critical speeds of minor danger. There are further critical regions, the extent of which increase with pulsating part of axial force and torsional moment, the number and extension of which decrease with magnitude of damping. Theory is illustrated by two numerical examples.

W. L. Esmeijer, Holland

3917. Cohen, H., and Handelman, G., On the vibration of a circular membrane with added mass, *J. acoust. Soc. Amer.* **29,** 2, 229-233, Feb. 1957.

Problem is one of a series dealing with the dynamic effect on structures produced by adding a mass of appreciable size. Subject paper deals with the effect of a rigid concentric circular mass of finite area on the frequencies of symmetric vibration of a membrane.

Authors use minimum principles to obtain some general properties of the eigenvalues. They also give plots showing the effects of the density and radius ratios on the eigenvalues.

Their results show that the membrane frequency may be raised or lowered by adding distributed mass. If the ratio of the mass density to membrane density is less than or equal to one, the lowest frequency is always increased. The higher frequencies may be raised or lowered depending on the ratio of the disk radius to that of the membrane. For high frequencies, the effect of the density ratio is of second order.

It is of interest to note that reviewer has shown [AMR **9,** Rev. 65] that stiffening a circular cylinder with rings can, for the lowest frequency, raise or lower the frequency of the combination in comparison to that of the unstiffened cylinder.

G. D. Galletly, USA

3918. Creech, M. D., McPherson, J. I., and Ammons, R. L., A method of locating the nodal points in undamped torsional vibration problems, *J. Amer. Soc. nav. Engrs.* **68,** 4, 805-808, Nov. 1956.

Authors present extension of method described in previous paper ["A method of finding the natural frequencies in undamped torsional vibration problems," title source **61,** 3, p. 592, Aug. 1949]. The general equation for the determination of the deflection of the r^{th} mass for a system vibrating with the n^{th} harmonic frequency is derived. A 4-cylinder engine and flywheel is used for a numerical example. The relative displacements of the five masses are computed, and relative displacement diagrams for each of the four modes are presented. The method permits the approximate numerical values of the natural frequencies (as computed in the previous paper) to be corrected "to any degree of accuracy desired."

J. N. Brennan, USA

3919. Vedeler, G., Vibration of frameworks, *European Shipbuilding* **5,** 6, 130-139, 1956.

A review is given of the determination of natural frequencies for transverse vibration of a beam. Author extends method of primary moments discussed in a previous paper [AMR **4,** Rev. 3184] to include oscillating loads on a structure. Side sway of frameworks about a vertical axis is discussed. Numerical examples of portal frameworks are included.

P. G. Jones, England

3920. Tobias, S. A., and Arnold, R. N., Part I—The influence of dynamical imperfection on the vibration of rotating disks, Part II—Tobias, S. A., Free undamped non-linear vibrations of imperfect circular disks, Instn. mech. Engrs., Preprint, 35 pp., 1957.

The first paper deals with the "stationary wave" which can develop in a rotating disk by the application of a stationary axial force at the periphery. Linear free and forced vibrations of stationary and rotating perfect and imperfect disks are discussed in detail. The resonance due to a stationary static force is considered. A high degree of perfection of the disk leads to the formation of a stationary wave, which may result in large deformations. With a small degree of imperfection the stationary wave virtually disappears; therefore, by controlled imperfection, it is possible to reduce the severity of this wave. Experimental studies with stationary and rotating disks are presented and correspond satisfactorily to the theory.

The second paper deals with the effect of stretching of the middle surface on the vibration of circular slightly imperfect disk. The nonlinear equations of motion are discussed, but the experimental facts, for the simplifying assumptions, have only a qualitative correspondence with the theory. Mathematical appendices, beautiful figures and diagrams, and references complete these very interesting papers.

G. Sestini, Italy

3921. Petrov, G. N., An instrument for automatically calculating the amount of unbalance in six planes of rotation (in Russian), "Problems of the theory of mechanisms and machines" Moscow, Mashgiz, 1955, 91-99; *Ref. Zh. Mekh.* 1956, Rev. 4222.

An instrument is described which enables the magnitudes and angular settings of the unbalance forces in six planes of rotation to be determined from the known unbalance values in two planes. The instrument has been developed by the chair of theory of Mechanisms and Machines of the Moscow Higher Technical College for a six-throw, automobile engine crankshaft and is based on the automatic resolution of the unbalance vectors in two of three given axial planes by means of a cam mechanism with three reciprocating tappets set at 120° and an electrical arrangement of special design. Determination of the unbalance forces in six given planes of rotation in the direction of the counterweights is effected by means of an electric computer. It is stated that determination of the unbalance values by this method requires only 1 minute, as against 25 minutes by calculation. The error of the instrument is within the permissible limits.

Courtesy Referativnyi Zhurnal F. M. Kurovskii, USSR
Translation, courtesy Ministry of Supply, England

Wave Motion in Solids, Impact

(See also Revs. 3920, 4008, 4036, 4046, 4110, 4243)

3922. Cunningham, D. M., and Goldsmith, W., An experimental investigation of beam stresses produced by oblique impact of a steel sphere, *J. appl. Mech.* **23,** 4, 606-611, Dec. 1956.

In this second article of a series of four (of which the first appeared in the *Proc. Soc. exp. Stress Anal.* **14,** 1, p. 179, 1956], authors describe the experimental results achieved by oblique impact.

Of particular interest are the inversions noted in the primary impact wave as it proceeds along the test beam. Accompanying the primary wave is a series of precursors whose presence is detected when strain-measuring devices make closely-spaced measurements possible, as in this test. As the major pulse decays there is a corresponding increase of the precursors.

Beam supports, clamped or free, have little effect on the wave until reflections from beam ends and supports occur.

This is the second of the projected four articles, and is therefore not a complete story in itself, but it sheds some interesting light on the nature of impact stresses.

A. G. H. Dietz, USA

3923. Koenigsberger, F., and Ghabrial, S. R., Impact stresses in drop hammer guides, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-12, 15 pp.

3924. Hess, J. L., The approximation of the response of the human torso to large rapidly applied upward accelerations by that of an elastic rod and comparison with ejection seat data, *Douglas Aircr. Co. Rep.* ES 26472, 51 pp., Nov. 1956.

It has been noticed that, when the human body is subjected to very rapidly applied accelerations, the accelerations at points of the body can be considerably larger than the maximum value of the applied acceleration. This paper considers the case when the acceleration is applied along the line of the spine from seat to head, as in ejection from aircraft, and attempts to approximate the motion of the human torso under these conditions by that of an idealized, one-dimensional, viscoelastic structure. The simple case of a homogeneous elastic rod is discussed in detail and its predictions compared with ejection-seat data. The extensions to more complicated viscoelastic structures are discussed. It is concluded that the elastic rod is a fairly good first approximation, but that it is not sufficiently exact to be used in making quantitative predictions. It is also concluded that more complicated structures will require more and better data for their evaluation.

From author's summary

3925. Usami, T., and Hirono, T., Elastic waves generated from a spheriodal cavity whose wall is subjected to normal stress of harmonic type, *Pap. Meteor. Geophys.* **7,** 3, 288–321, Oct. 1956.

Paper deals with wave generation from a spheroidal origin to get a possible interpretation for push-pull distribution of seismic waves. Authors apply prolate spheroidal functions studied by Chu and Stratton ["Elliptic cylinder and spheroidal wave functions," 1941] to solve wave equations given with respect to spheroidal coordinates. It was assumed that $\lambda = \mu$ in the medium and that the surface of origin was subjected only to normal stress working periodically.

Equations of stress, expanded into series, were reduced to a set of simultaneous equations, which were solved numerically to satisfy boundary conditions in the cases of different ellipticity of origin and of different values of ratio of wave length to longer axis of origin. Azimuthal distributions of radial and transversal displacements at a great distance were drawn from the results, which showed patterns of quadrant type to be observed in some cases of wave generation.

H. Kasahara, Japan

3926. Ghosh, S. K., Deformation of a fixed-free bar under a compressive impact of short duration, *Indian J. Phys.* **30,** 9, 485–486, Sept. 1956.

Present paper gives a quantitative explanation, from the theory already developed by the author in a series of papers, of the fact regarding the deformation of a fixed-free bar under a compressive impact of short duration. The experimental data supplied by E. T. Habib are used in testing the theory. The agreement between author's theory and experiment is found to be satisfactory.

From author's summary

3927. Veltkamp, G. W., On Kelvin and Poincare-waves in a strip, *Math. Centrum Amsterdam. Rap.* TW 37, 13 pp., May 1956.

3928. Sidlyar, M. M., The two-dimensional dynamic problem of the stress distribution in an elastic circular cylinder (in Ukrainian), Scient. Memoranda, Kiev State University **12,** 6, 7–74, 1953; *Ref. Zh. Mekh.* 1956, Rev. 3877.

Methods of operational calculus are used to solve the two-dimensional problem of the stress condition in a circular cylinder for the case that uniformly distributed radial forces and moments are abruptly applied to the envelope. It is assumed that in the initial instant the body is at rest. The results are expressed in Bessel functions.

Courtesy Referativnyi Zhurnal S. A. Tersenov, USSR
Translation, courtesy Ministry of Supply, England

Elasticity Theory

(See also Revs. 3887, 3894, 3898, 3928, 3942, 3947, 3948, 3952, 3969, 3982, 3993, 4011, 4040, 4044, 4045, 4046, 4047, 4161, 4176)

3929. Blackburn, W. S., and Green, A. E., Second-order torsion and bending of isotropic elastic cylinders, *Proc. roy. Soc. Lond. (A)* **240,** 1222, 408–422, June 1957.

Second-order torsion of a cylinder of compressible isotropic material is reduced to the solution of a single boundary-value problem involving two complex potential functions. Without solving this boundary-value problem, a formula for the fractional elongation of the cylinder is obtained in agreement with that found previously by Rivlin [AMR **7,** Rev. 2709]. When the region occupied by any cross section of the cylinder is bounded by a single closed curve, the equation satisfied by the complex potentials reduces to that obtained by Green and Shield [AMR **5,** Rev. 1015] for the case of an incompressible cylinder, and a general method of solution was given by these authors.

Second-order bending of a cylinder of compressible isotropic material by couples over its plane ends is also reduced to the solution of a single boundary-value problem for two complex potential functions, in addition to the boundary-value problem for classical torsion of a cylinder. A general formula is found for the change in length of the line of centroids, and one application of the theory is made to right circular cylinders.

From authors' summary by S. H. Crandall, USA

3930. Jaeger, L. G., The analysis of grid frameworks of negligible torsional stiffness by means of basic functions, *Proc. Instn. civ. Engrs.* **6,** 735–757, Apr. 1957.

Paper forms a review of the analysis of simply supported grids with negligible torsional stiffness, using orthodox harmonic analysis, and taking a very simple grid for purposes of explanation. It forms a preliminary step to the theory involved in the analysis of simply supported grid frameworks. The simple vehicle adopted for explaining the method is a system of grids supported on two sides. The method can be also extended to cover grids supported on three or four sides, or even for interconnected portal frames. Given loading on a grid framework is analyzed into "basic" components, and distribution coefficients are derived for each component in turn. This distribution can be regarded, with equal validity, according to author, as a distribution of load, or of bending moment, or of deflection. The analysis rests only on one simplifying assumption that the transverse members of the grid may be replaced by a uniform continuous medium of the same total flexural rigidity.

S. K. Ghaswala, India

3931. Tiedemann, D., Torsion of split hollow cylinders and of bars of special section with rounded corners (in German), *Forsch. Geb. Ing.Wes.* **23,** 1/2, 27–28, 1957.

Author uses membrane analogy for the shapes he investigates. For case where the shape of the bar's cross section is a segment of a ring of thickness b, internal radius a, he finds by membrane theory the maximum stress $\tau_{max} = f(b/a)$. This is the maximum stress also in the rounded corners of the special shapes considered. It is compared with the stress in the straight legs of their section (τ_1) giving a stress concentration factor $k = \tau_{max}/\tau_1 = 1 + 0.15(b/a)$. Author intends to check results by photoelastic methods.

E. G. Chilton, USA

3932. Mansfield, E. H., The torsional rigidity of solid cylinders of double-wedge section, *Aero. Res. Counc. Lond. Rep. Mem.* 2959, 7 pp., 1956.

The torsional rigidity of solid cylinders of double-wedge section is considered theoretically. Minimum energy methods are used to

determine close upper and lower limits to the rigidity. The results are presented in graphical form. G. G. Meyerhof, Canada

3933. Galimkhanov, K. G., A new method of calculating the torsion of shafts of prismatic cross section (in Russian), *Trudi Ufimsk. aviats. in-ta* 1, 66–87, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4626.

An approximate method is presented of solving problems of the torsional theory of prismatic bars, suitable for closed sections having several axes of symmetry. The stress function is written as the sum of a finite number of terms:

$$\varphi = A_0 + \sum_{m=1}^{S} A_m \frac{\rho}{r}^{\frac{m\pi}{\alpha}} \cos \frac{m\pi\psi}{\alpha} - \frac{G\vartheta}{2}\rho^2$$

in which α is angle at the apex of the sector delimited in the section in question by the symmetry axes.

The constants A_m must be determined by the conditions on the profile, assumed to be formed of arc segments of the base circle and its chords. The author suggests reducing to zero, not the actual function φ, but its integrals along rectilinear and curvilinear segments of the contour, and furthermore, to support this, applying the function itself and its derivative for some points on the contour.

Calculations are made for an equilateral triangle and a square. In the triangular case, author's solution agrees with the rigorous solution; the error of the approximate solution for the square is likewise insignificant (< 1%). V. K. Prokopov, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

3934. Paria, G., Elastic stress distribution in a three-layered system due to a concentrated force, *Bull. Calcutta math. Soc.* **48,** 2, 75–81, June 1956.

Paper deals with calculation of stresses in the interior of a semi-infinite elastic body with two plane elastic covering layers of constant finite depth and subjected to a concentrated normal load at the outer boundary of the top layer. Solution is obtained by means of the Hankel transform of the stress function which leads to a system of eight linear equations.

Numerical results are given for a concrete-gravel-soil system. An "equivalent depth" formula is developed by which the upper layers can be replaced by a depth of the underlying material for stress calculation. This reduces the problem to that of Boussinesq, but only insofar as stresses along the load axis are concerned. Numerous typographical errors are obvious but do not interfere with the clarity of the paper. C. T. West, USA

3935. McCutchen, W. R., A treatment of self-gravitational strains in the earth, *Trans. Amer. geophys. Un.* **38,** 1, 95–98, Feb. 1957.

Treating the earth as a sphere and assuming density and elastic properties to be functions of the radius only, author derives an approximate equation for the radial displacement due to gravitation. Equation is then solved by assuming an appropriate density distribution and dividing the radial interval into a number of zones. In each zone, density distribution and elastic properties (seismic velocity) are approximated by constants or linear functions. A radial contraction at the earth's surface of about 188 km is obtained. H. Parkus, USA

3936. Trifan, D., On the complementary energy principle, *J. Math. Mech.* **6,** 1, 87–90, Jan. 1957.

3937. Fridman, Ya. B., and Sobolev, N. D., Estimating and increasing the strength of solids made of isotropic nonhomogeneous materials (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **105,** 6, 1166–1169, Dec. 1955.

3938. Hognestad, E., Confirmation of inelastic stress distribution in concrete, *Proc. Amer. Soc. civ. Engrs.* **83,** ST 2 (*J. Struct. Div.*), Pap. 1189, 18 pp., Mar. 1957.

Studies reported in the literature regarding inelastic stress distribution in flexure of reinforced-concrete members are reviewed, and the results obtained are compared to the recommendations of the Joint ASCE-ACI Committee on Ultimate Strength Design. Test results show that the inelastic concrete stress distribution consists of a rising curve from zero to the maximum stress and a descending curve beyond the maximum stress. A simplified rectangular distribution gives a satisfactory accuracy for the common practical design cases. The Joint Committee design coefficients are well substantiated by test results.

From author's summary

3939. Fletcher, G. C., The thermal expansion of solids, *Phil. Mag.* (8) **2,** 17, 639–648, May 1957.

The assumptions underlying Grüneisen's formulas for the thermal expansion of solids are examined. It is shown that they lead to a coefficient of expansion which is an increasing function of temperature at temperatures above the Debye temperature. Fischmeister [*Acta Cryst.* **9,** 5, 405–474, May 1956] concluded that the observed increase in the expansion of the alkali halides at high temperatures was explained by this theory. Author shows that observed increase greatly exceeds theoretical.

F. R. N. Nabarro, S. Africa

3940. Kostiuk, A. G., Determining temperature distribution and temperature stresses in turbine disks (in Russian), *Teploenergetika* **3,** 3, 3–9, Mar. 1956.

There are many cases in determining temperature field and thermal stress in turbine disks where it is not sufficient to calculate under the customary simplified assumption of a constant temperature along the thickness of the disk. For instance, in treating turbines with one-sided cooling, the temperature gradient in the axial direction is taken into account, and the paper under consideration gives a general approximate method for finding, in such cases, the temperature distribution within the disk. Comparison of exact and approximate results valid for the elementary special case of a disk with constant thickness shows that author's method is sufficiently exact except for a quite small region close to the edge of the disk; here the difference amounts to 28%.

Author also gives his own approximate way for determining thermal stresses when the spatial distribution of temperature in the disk shows axial symmetry. The author's method has several advantages: it can be applied to disks of any profile; it allows to respect the dependence between material constants and temperature; and finally, it is not necessary to substitute, in the well-known rather complicated way, the fictitious step profile to the actual shape of the disk.

All the deductions are clear from the mathematical, and quite natural from the technical, point of view. Illustrative diagrams and practical example raise the value of this carefully written paper, which is doubtless a welcome contribution to the theory of turbines. V. Vodicka, Czechoslovakia

3941. Mura, T., and Kinoshita, N., Expression of initial stresses based on Green's functions, *J. Japan Soc. aero. Engng.* **5,** 36, 7–10, Jan. 1957.

When a body whose boundary is free of external force is heated or cooled, two questions arise: (1) when is the thermal stress a maximum, (2) what is the maximum value? The author devises a method of answering these questions, by means of Green's functions when the Eigenspannungsquellen [H. Reissner, *ZAMM* **11,** no. 8, 1931] are given. L. M. Milne-Thomson, USA

Experimental Stress Analysis

(See also Revs. 3963, 3973, 3981, 4007)

3942. Kuhn, R., Experiences in strain measurements in concrete bodies of large dimensions (in German), *ZVDI* **99,** 17, 751-763, June 1957.

Large concrete bodies are subjected during the hardening of the concrete and thereafter to considerable strains resulting from a difference in temperature between the core and the outside faces and also from the shrinkage of the concrete. These strains can be of the same order of magnitude as the strains due to the loads applied on the body. They are not easily computed.

In order to obtain information about the importance of temperature and shrinkage stresses, author uses various strain gages. He describes some features of these gages, the method of fastening them to the concrete reinforcement, the considerations for the selection of the location and orientation of these instruments, and, more generally, for the planning and evaluation of the whole experimentation. The time evolution of the strains over a period, sometimes as long as three years, is illustrated by a great number of strain recordings for various locations of the gages in various elements of concrete dams. They show in some cases a satisfactory agreement between the measured strains and those indicated by optical methods.

This paper brings a very valuable contribution to the evaluation of temperature and shrinkage stresses in large concrete bodies.

H. M. Trent, USA

3943. Barker, R. S., and Murtland, J. B., Protection of underwater SR-4 strain-gage installations on tunnel liner of a hydroelectric development, *Proc. Soc. exp. Stress Anal.* **14,** 2, 131-138, 1957.

The method developed for the waterproofing and protection from mechanical damage of SR-4 strain-gage installations on the inside surface of a steel tunnel liner is described. A few liner stresses are given to demonstrate the effectiveness of the protective measures used. From authors' summary

3944. Mehringer, F. J., and Cooper, W. E., Experimental determinations of stresses in the vicinity of pipe appendages to a cylindrical shell, *Proc. Soc. exp. Stress Anal.* **14,** 2, 159-174, 1957.

Paper considers the experimental determination of stresses in a cylindrical shell in the vicinity of appendages resulting from various types of reactions that might be exerted on pipes and internal pressure. The components of the reactions considered are radial thrust, longitudinal and circumferential moments with respect to the cylindrical shell.

Stresses were determined along the generatrix and meridian of the shell through the intersection of the centerline of the appendages and the shell surface. The results reported are the longitudinal and circumferential stresses on both the inner and outer surfaces of the shell for three appendages of various diameters attached to a thin-walled shell. The experimental techniques involved in obtaining these results are discussed. Deflections of the shell due to reactions on the appendages were also measured. These data are included. From authors' summary

3945. Ruff, W., Gottfried, M., and Schillmoller, P., On the determination of the modulus of elasticity for small machine parts (in German), *Z. Metallk.* **48,** 3, 119-125, Mar. 1957.

The relative merits and weaknesses of mechanical and electrical extensometers for measuring strains over a short gage length are discussed. An extensometer having a 2-mm gage length is described. It signals movement of the points by changing the rate of leakage of air from a constant-pressure (0.2-0.3 atm) supply. Unfortunately, the method of calibration of this gage does not seem to be given, although several experiments were carried out to insure reproducibility of the results.

The experiments described were conducted to determine the modulus of elasticity at various places on piston rings. E was determined by dividing the stress calculated by customary curved beam formulas by the measured deformations at points inside and outside the ring.

Measurements were made on cast iron, steel, and various aluminum alloys. Tests conducted on constant-moment beams revealed slightly higher moduli on the compression side than on the tension side, convergent at zero load, and both values decreasing as the load increased. C. E. Balleisen, USA

3946. Cook, N. H., A differential torsion testing machine, *Proc. Soc. exp. Stress Anal.* **14,** 2, 155-158, 1957.

A method is described for obtaining torsional stress-strain data that are not ambiguous as to strain rate (as is generally the case). This is accomplished by simultaneously testing two specimens of slightly different size and measuring the difference in twisting moment. A machine is described which performs the tests in a very simple manner. From author's summary

3947. Theocaris, P. S., On an electrical analogy method for the separation of principal stresses along stress trajectories, *Proc. Soc. exp. Stress Anal.* **14,** 2, 11-20, 1957.

The method consists of constructing directly the stress trajectories and separating the principal stresses along these curves by graphical integration.

The direct construction of stress trajectories is obtained by applying the existing analogy between electric potential and the value of the parameter of curves representing the stress trajectories. Thus, the stress trajectories are traced very accurately and moreover their density is determined so that the distance between them gives the differential parameter of first order of the functions expressing these curves.

For the separation of principal stresses, the Lame-Maxwell equations have been transformed into a form that avoids the use of isoclinics as auxiliary curves. The results obtained depend only on the values of principal stress difference and therefore are very accurate.

The accuracy of this method is confirmed by comparison with the results obtained by using either the analytic method or Filon's method of graphical integration.

The necessary equipment and the procedure for the construction of stress trajectories are very simple, and the time needed for the application of the method is less than with the other approximate methods.

From author's summary by T. A. Hewson, USA

Rods, Beams, Cables, Machine Elements

(See also Revs. 3916, 3919, 3920, 3922, 3929, 3983, 3994, 3999, 4128)

3948. Higuchi, S., Saito, H., and Hashimoto, C., A study of the approximate theory of an elastic thick beam, *Canad. J. Phys.* **35,** 6, 757-765, June 1957.

Authors extend the analytical investigation of the natural vibration of "thick" (deep) beams, which two of them had previously reported upon. An exact solution of the general case is not accomplished. However, thick beams with various, specific end conditions are solved. Corresponding natural frequencies are then deduced numerically. Finally, comparisons are made with values obtained using the elementary thin-beam theory. The angular frequencies obtained are derived based on simplifying assumptions of end conditions. It is concluded that the thicker the beam the smaller the frequency calculated using the thick-beam approach as

compared with the elementary solution. The error involved in the thin-beam solution of the most serious case, a free-free beam of $l/c = 5$, is only 10%. Arranged in the order of decreasing error occurring when the elementary solution is used, the beams are free-free, clamped-clamped, supported-supported and clamped-free, respectively. J. P. Vidosic, USA

3949. Acharya, Y. V. G., Elasto-plastic bending of a beam under plane strain conditions, *J. aero. Soc. India* **9**, 1, 8–13, Feb. 1957.

The bending of a beam, having a rectangular transverse section, under the action of a pure couple is investigated. It is shown that the application of von Mises' hypothesis yields a higher resisting moment than would be obtained by using Tresca's assumptions. Numerical values of moment coefficients have been derived, using both hypotheses and including the effects of two distinct yield limits, as well as the effect of Poisson, Author also evaluates a comparative coefficient u, which gives the ratio of the moment coefficient obtained by using the two hypotheses. The extension of this method to more complicated situations can be easily done.
From author's summary by A. H. Finlay, Canada

3950. Bolotin, V. V., The stability of the two-dimensional form of bending of beams connected by elastic tie members (in Russian), "Calculation of strength, rigidity, stability and oscillation," Moscow, Mashgiz, 1955, 223–230; *Ref. Zh. Mekh.* 1956, Rev. 4745.

On the basis of the general differential equations for bending and torsion derived by V. Z. Vlasov for thin-walled box beams of closed section with a deformable contour, a solution is put forward for the problem of the stability of the two-dimensional form of bending in a system of beams connected by tie members. It is assumed that, when stability is lost, both rotation of the beam with bending of the ties and rotation of the entire compound section as a whole are possible. The method of energy analysis is used. The energy of bending and torsion of the principal beam members and the energy of deformation of the ties are included in the calculation.

The critical loading parameter is found by equating to zero the determinant of three equations incorporating the rigidity characteristics of the ties and beams. With insufficient rigidity of the ties, the solution becomes identical with the formula of S. P. Timoshenko for the case when rigid rotation of the cross section is absent [S.P. Timoshenko, *Izv. politekh. in-ta*, 1910].
Courtesy Referativnyi Zhurnal O. N. Kondakova, USSR
Translation, courtesy Ministry of Supply, England

3951. Moshensky, N. L., The dynamic load-carrying power of beams bent in compression (in Russian), *Trudi Leningr. korablestroit in-ta* no. 12, 91–102, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4683.

An examination of the deformation of a freely supported prismatic bar having an initial sinusoidal curvature under the action of an abruptly applied and subsequently abruptly removed compressive force. Expressions are obtained for calculating the stresses in the bar, and the relationships are derived for determining the critical condition when a plastic hinge forms in the center of the span, it being assumed that this plastic hinge forms instantaneously.

Calculations are made for standard bulb-plate sections attached to the deck plating, and it is shown that the dynamic load-carrying power may be both greater and less than the static strength, depending on the ratio β between the duration of loading and the period of the first mode of free oscillation of the bar. The least load-carrying power is obtained at $\beta = 0.55$–0.70, and represents 0.65–0.8 of the corresponding value under static loading.
Courtesy Referativnyi Zhurnal V. S. Chuvikovskii, USSR
Translation, courtesy Ministry of Supply, England

3952. Szelagowski, F., An elastic circular ring subjected to an arbitrary load, *Bull. Acad. Polonaise Sci. Cl. (IV)* **5**, 2, 67–75, 1957.

Title problem was solved by the complex variable method. Reviewer is disappointed to see that N. I. Muskhelishvili's well-known monograph ["Some basic problems of the mathematical theory of elasticity"; AMR **7**, Rev. 2099] was not even mentioned, although G. V. Kolosov's earlier work ["Application of complex variable in the theory of elasticity," Leningrad-Moscow, 1935] was cited. In fact, a simpler but much more thorough treatment of the circular ring problem had already been given in Muskhelisvili's book. Y. Y. Yu, USA

3953. Tuplin, W. A., Compound epicyclic gear trains, *Mach. Design* **29**, 7, 100–104, Apr. 1957.

Article examines practical possibilities and limitations of four-gear epicyclic train in drive applications so that maximum efficiency is achieved at high velocity ratios. Principles are applicable to any type of epicyclic gear train. It is shown that for normal proportions efficiency of epicyclic train is given approximately by $1/\epsilon = 1 + 0.2(r_A + r_C - r_B - r_D)(m - 1)$ where ϵ = efficiency, m velocity ratio of the gear train, r the reciprocal of the number of teeth, A and C refer to the compound planet gear and B, D refer to the internal gears meshing with A, C, respectively. Following table gives efficiencies of various high ratio trains:

Ratio	Number of teeth in				Efficiency
	Planet A	Meshing Internal B	Planet C	Meshing Internal D	
256	16	34	15	32	0.24
	48	102	45	96	0.46
	96	119	90	112	0.82
2000	45	92	44	90	0.10
	Over-all ratio of 2000 obtained by use of 96/119/90/112 train above with 8 : 1 spur train				0.79

Conclusion is reached that to minimize losses it is necessary to (1) use internal gears as fixed and driven members; (2) make diameters to planet gears more than half as large as those of the internal gears; and (3) keep numbers of teeth in the 80 to 150 range. E. M'Ewen, England

3954. Semar, H. W., and McGinnis, R. E., Experimental determination of gear tooth stresses in large marine gears, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-117, 6 pp.

3955. Zlatopolsky, M. D., Foundations of the theory of conjugation and new methods of research and design of three-dimensional toothed gears (in Russian), *Trudi Leningr. tekhnol. in-ta im. Lensoveta* **32**, 46–62, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4217.

The theory of conjugate planes generalizing the Hochmann-Olivier theory and the application of the differential calculus to the design of three-dimensional toothed gears are examined.

Two theorems of Hochmann-Olivier [Kh. 1. Hachmann: "Theory of gears," Odessa (886)], relating to conjugated and neutrally enveloping surfaces are examined, and, on the basis of the theory of the helix, three theorems of conjugation are set up.

It is shown how these theorems can be applied to the determination of the characteristics of instantaneous contact lines formed in rack-wheel systems of toothed gears between the toothed and washing surfaces. The examples adduced include the washing of surfaces toothed by the rolling contact of a hob, and the characteristic equation of the system of a gear-cutting lathe is derived.

A method for the analysis and synthesis of toothed gears, using differential geometry, is described; and also investigated are the curves obtained by the intersection of surfaces and coordinate

plates in the points of reciprocal contact of these curves with their intersections. In particular it is demonstrated that any three-dimensional gear can be reduced to an ordinary system of two equivalent spur wheels meshing in the same plane and cut by an equivalent rectilinear rack; this is a simplication of Treadgold's method. The same method is applied to the analysis of three-dimensional gears in coordinate planes of an accompanying trihedron. M. G. Serebrennikov, USSR

Courtesy Referativnyi Zhurnal
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Plates, Disks, Shells, Membranes

(See also Revs. 3920, 3931, 3932, 3934, 3944, 3974, 3975, 3976, 3977, 3978, 3979, 3980, 3981, 3982, 3998, 4208)

3956. Sanders, J. L., Jr., McComb, H. G., Jr., and Schlechte, F. R., A variational theorem for creep with applications to plates and columns, *NACA TN* 4003, 23 pp., May 1957.

A variational theorem for creep has been formulated which is an extension of a variational theorem developed by Reissner. Various systems of equations leading to approximate solutions to problems of the creep behavior of plates, columns, beams and shells may be obtained by using direct methods of the calculus of variations in conjunction with the stated theorem. The application of the theorem is illustrated for plates and columns by the solution of two sample problems.

From authors' summary by Frank Garofalo, USA

3957. Horvay, G., Biharmonic eigenvalue problem of the semi-infinite strip, *Quart. appl. Math.* **15,** 1, 65–81, Apr. 1957.

Consider solutions of $\Delta\Delta u = 0$ in the half-strip $0 \leq x < \infty$, $-1 \leq y \leq 1$ clamped along the long edges: $u = u = 0$ at $y = \pm 1$. There is among these an infinite sequence of solutions exponential in x (Fadle-Papkovitch eigenfunction). Problem 1: Are these eigenfunctions complete? Problem 2: How to find the expansion coefficients of a solution with given data on the short side $x = 0$? (These eigenfunctions come from a nonselfadjoint operator.) These problems have been solved by R. C. T. Smith [*Australian J. sci. Research* **5,** p. 227, 1952; (problem 2 in case u and Δu are prescribed at $x = 0$)].

In this paper, author gives a novel solution of these problems, based on an explicit series expansion of solutions for which u and Δu are polynomials in y at $x = 0$. After subtracting a polynomial biharmonic function and reflecting across $x = 0$ the values of u and u_y at $y = \pm 1$ are determined for $x < 0$. The resulting boundary-value problem in the whole strip is solved by Fourier integral, and the solution is expanded in an infinite series with the aid of residue calculus. These series expansions are used to compare exact solutions with approximate ones constructed by a method developed previously by the author. P. D. Lax, USA

3958. Okabayashi, M., Tension of a strip with several equidiametric circular holes placed arbitrarily (in Japanese), *Trans. Japan Soc. civ. Engng.* **43,** 11–22, Feb. 1957.

The elastic solution of the stress distribution of a thin plate having a single hole and subject to tension was given by G. Kirsch, where both the length and the width of the plate were assumed infinitely large. His solution can be understood as the sum of two stress functions: The first function is the stress function of a plate without the hole, and the second is that which cancels the effect of the first on the boundary of the hole. The effect is small at the point far from the center of the circle.

In the present paper, an approximate solution is given to a strip with several equidiametric circular holes placed arbitrarily and subject to tension, through successive applications of the method mentioned. If distances between the boundaries are not small, a few repetitions of this operation gives practically satisfactory results. A formula for estimating the stress concentrations on the circular boundaries is derived. S. Okamoto, Japan

3959. Bromberg, E., Non-linear bending of a circular plate under normal pressure, *Comm. pure appl. Math.* **9,** 4, 633–659, Nov. 1956.

Author treats the title problem for a wide range of loads and thicknesses of the plate. At the boundary, three distinct conditions are specified: (a) no circumferential strain and slope; (b) no circumferential strain and radial moment, and (c) no radial stress and bending. Solutions are characterized by a single parameter k, which is proportional to $(N/E)^{\frac{1}{3}}(R/h)^{\frac{4}{3}}$, where N is load per unit area, E Young's modulus, R and h, radius and thickness of the plate, respectively.

For $k \leqslant 1$, solutions are obtained by a perturbation expansion with respect to k^2; for $1 \leqslant k \leqslant 15$, a power series in $(r/R)^2$ is used, where r is radial distance of a point from origin. For $15 \leqslant k \leqslant \infty$, however, the series solution becomes too laborious, hence the boundary-layer theory is used. By extending the existing asymptotic method, a single expression for both the boundary layer and the interior of the plate is obtained. Author claims that the single expression gives approximations more accurate than those given by expressions obtained separately for the boundary layer and the interior of the plate. D. H. Cheng, USA

3960. Osseledko, A. I., The bending of trapezoidal plates (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **21,** 142–150, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4647.

The problem is investigated of the bending of an equilateral trapezoidal plate constrained along its edge. For the approximate solution of the problem author uses the method of V. Z. Vlasov (reduction to an ordinary differential equation) and Bubnov's method.

The final expressions are given for the bending deflection, the derivation of which by Bubnov's method proved to be the simplest. Experimental investigations have been made on trapezoidal plates made of Perspex. The dimensions of the plates were: thickness, 3 and 5 mm, length of base 209 and 189 mm, height 245 mm. The plates were tested under uniformly distributed load provided by a column of water. Only the bending deflection was measured.

Comparison of the experimental and analytical results showed that V. Z. Vlasov's method gives better agreement. The paper contains typographical errors on p. 149.

The calculation of trapezoidal plates freely supported at the edges has also been discussed by the present abstractor [*Sb. in-ta stroit. mekh. Akad Nauk USSR*, no. 10, 1940].

Courtesy Referativnyi Zhurnal P. M. Varvak, USSR
Translation, courtesy Ministry of Supply, England

3961. Barta, J., Circular plate uniformly loaded on a diameter, *Acta Techn. Hung. Budapest* **16,** 3/4, 400–406, 1956.

The usual theory of bending of a thin elastic plate is applied to the case mentioned in the title. The case of a clamped circular plate and the case of a simply supported circular plate are discussed separately. The problem is solved by means of biharmonic series. The numerical value of the bending moment is computed in several points. From author's summary

3962. Nowinski, J., Application of Laplace transformation for the determination of arch deflection (in Polish), *Rozprawy Inż.* **4,** 3, 413–428, 1956.

Author presents a method for establishing the equation of the deflection curve of the longitudinal axis of a plane parabolic arch with constant cross section and small curvature, arbitrarily supported at both ends and arbitrarily loaded in the direction normal to the line, connecting the ends.

Using the Laplace transformation, a universal equation of a deflection line for various kinds of load and various arch supports

is obtained. Constant parameters of this function can be determined using the known boundary conditions.

Two solutions are presented, the first concerning stiff, the other, supple arches.

A numerical example is given using general solution.

J. Czulak, Poland

3963. Chronowicz, A., Anisotropic cylindrical shells, *Civ. Engng., Lond.* **52,** 611, 546–549, May 1957.

Paper sets out the mathematical steps necessary for the structural analysis of the anisotropic shell, a shell in which the flexural rigidity differs in the directions of the cylindrical coordinate axes due to stiffening ribs. To illustrate the method, the differential equation of cylindrical shells by Finsterwalder is adapted to the analysis of a shell with circumferential ribs below the shell slab, and a numerical example is included.

Complete evaluation of the two-span structure is not dealt with to finality.

P. Whitton, England

3964. Nakamura, K., A contribution to the analysis of stresses in the toroidal shell of circular cross section, *Bull. Fac. Engng., Yokohama nat. Univ.* **6,** 103–109, Mar. 1957.

Tables are given with the aid of which the stresses in thin toroidal shells with circular cross section under uniform pressure can rapidly be calculated. Method can be used as a simple solution for the stresses in a spherical head of a pressure vessel.

M. Botman, Canada

3965. Favre, H., Contribution to the study of cylindrical shells with variable thickness (in French), **Part I and II,** *Bull. tech. Suisse Rom.* **82;** 23, 419–427, Nov. 1956; **82;** 24, 431–438, Nov. 1956.

Paper discusses a method for calculation of stresses and moments in a cylindrical shell with thickness which varies linearly along the length of the shell, the middle surface of the shell being a cylinder of radius a. The paper is in two parts; part 1 deals with the theory; part 2 deals with applications. The radial displacement component w is obtained in the form of a series in increasing powers of a parameter which characterizes the variation in thickness. The series converges rapidly (first two terms give good results) for the case of a couple and a shear force applied to the end of a relatively long shell provided that the variation of thickness is sufficiently gradual, and relatively simple formulas are obtained for the stresses and the moments in the shell. These formulas are applied (a) to the problem of a conduit subjected to constant internal pressure for various end conditions and for several variations of thickness, and (b) to the problem of the cylindrical reservoir filled with a liquid. The formulas appear to be simpler than those derived by Reissner and by Meissner. However, as is usual in series solutions if the series parameter which characterizes the variation of thickness is large, the convergence is poor, and accurate evaluation of moments and stresses requires a large number of terms.

A. P. Boresi, USA

3966. Alumae, N. A., Presentation of the fundamental relations in the nonlinear theory of shells (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 136–139, Jan./Feb. 1956.

In linear theory of thin shells the homogeneous equilibrium conditions for internal unit forces and moments form an analogous set of equations to compatibility conditions for components of two deformation tensors. If all components are symmetrical with respect to both Gauss coordinates of the middle surface, they can be chosen so that they appear also in the expression for the elastic energy of the shell, and troubles in satisfying the moment equilibrium condition about the normal to the middle surface or to an analogous nondifferential geometrical equation can be avoided. Using tensor notation author shows in a very succinct manner that, by a suitable choice of tensor components, the same can be done in the nonlinear theory. The equilibrium conditions 2.9 – 2.12 for force and moment components S^{ij}, G^{ij}, Q^i and S are derived from the principle of virtual displacements and are analogous to six geometrical conditions 2.15 – 2.18. If nonlinear terms are neglected, the equations differ from those given by Novozhilov [AMR **9,** Rev. 706]. From general equilibrium conditions author derives differential equations for critical values of unit forces for an initially membrane state of stress.

A. Kuhelj, Yugoslavia

3967. Leyko, J., The strength of a conical shell with ribs subjected to an axially symmetrical load (in Polish), *Rozprawy Inż.* **4,** 2, 307–324, 1956.

A ribbed shell is treated as an orthotropic structure. It is supposed that the dimensions of the cross sections are chosen in such a way that the substitute rigidities of the shell, constituting a whole with the ribs, are constant. Thus the problem can be stated using a system of differential equations with constant coefficients.

Using Meissner variables, author reduces the problem to that of a solution of a differential linear equation of the fourth order with constant coefficients.

The solution of the homogeneous equation is presented in the form of an asymptotic series or, by rejecting the small expressions (according to the "engineers' theory of boundary effect" of Geckeler), in the form of a simple formula.

The solution for a membrane state of stress is a particular integral of the nonhomogeneous problem.

A. Kornecki, Poland

3968. Oravas, G., Analysis of thin doubly curved nearly cylindrical shells of rotation by the method of successive corrections, *Publ. int. Assn. Bridge struct. Engng.* **16,** 425–438, 1956.

The shells of revolution are considered to be "nearly cylindrical" if the variation of the radius of revolution is small compared with the mean radius. Examples cited are slightly corrugated, barrel-shaped and bell-shaped shells. Paper shows how a power-series solution for the normal deflections produced by normal pressure loading can be obtained by expanding all terms in the equations of equilibrium as power series of a small parameter related to the variation in shell radius. Longitudinal stresses are assumed negligible.

Reviewer comments that, although not stated explicitly, requirements of accuracy include restrictions on the magnitude of the *slope* of the undeformed shell with respect to its axis.

L. Maunder, Scotland

3969. Yu, Y.-Y., Rational analysis of heat-exchanger tube-sheet stresses, *J. appl. Mech.* **23,** 3, 468–472, Sept. 1956.

Interaction between tube sheet and attached shells is evaluated. Value of refinement has been questioned because of other unknowns [see discussion and closure: title source **24,** 2, 315–321, June 1957]. Right-hand sides of author's equations [2] must be multiplied by one half to be consistent with his reference.

A. G. Holms, USA

3970. Randolph, L. F., End reactions and stresses in pipelines, *Engineering* **182,** 4728, 492–496, Oct. 1956; **182,** 4730, 555–558, Nov. 1956.

Subtitle of paper is "Simplified calculations for two- and three-dimensional layouts," to the first word of which the reviewer is inclined to prefix the word "Over." Besides making certain conventional approximations, author uses additional empirical assumptions and corrections to the point that reviewer would not

feel consistently safe in relying upon author's claim to an accuracy of "about 20%." It looks as if the procedure of the paper would not generally satisfy the requirements of the 1955 ASA Code for Pressure Piping.

Reviewer disputes basic philosophy of having each designer do his own piping flexibility calculations, especially for important systems where the cost per foot of piping is so high that saving 20 ft can sometimes pay for several rather accurate calculations. If much piping work is done regularly, the engineer can usually justify using a digital computer on economic grounds; see, e.g. Jackson & Johnson [AMR **8**, Rev. 963]. If only occasional piping analysis is done, then the pitfalls are such that the work might well be placed with suitable consultants. Reviewer believes that chief justification for approximate methods is in noncritical cases where other considerations dictate an ultraconservative design, and only a rough check of system safety is necessary. If potentially-treacherous approximate methods are to be used at all, the simple "square-corner approximation" would seem to be sufficiently straightforward, and can be carried out by clerical help.

Second part of paper is devoted to examples and supporting appendices. J. L. Lubkin, USA

Buckling Problems

(See also Rev. 4000)

3971. Madejski, M., The buckling of a prismatic bar as a problem of dynamical theory of plasticity (in Polish), *Rozprawy Inż.* **4**, 3, 351–366, 1956.

Since the failure of a compressed bar, in the stage of plastic deformation (postelastic buckling) depends on time, longitudinal bending of a prismatic cantilever with the following assumptions is considered: (1) the bar has an initial curvature; (2) the axial force changes with time according to the law: $P(t) = 0$ for $t = -0$ and $P(t) = \text{const}$ for $t = +0$, until the first fissure appears ($t = T$); (3) the stresses in the entire cross section and during the whole period of action of the force exceed the real elastic limit; (4) the phenomenon is isothermal and tautotermic.

The considerations are based on the relation between the rate of load increase and that of stress increase. This relation is obtained in the author's paper on the dynamical theory of plasticity, not yet published. A criterion for the appearance of the first fissure is established; for bars of identical dimensions it represents the dependency between the "buckling" force and time, material and geometrical parameters of the bar, and the so-called period of isothermal relaxation. The range of applicability of the formulas derived is determined. This method is also applicable for elastic-plastic buckling. M. Piątek, Poland

3972. Viest, I. M., Elstner, R. C., and Hognestad, E., Sustained load strength of eccentrically loaded short reinforced concrete columns, *J. Amer. Concr. Inst.* **27**, 727–755, Mar. 1956.

The principal object of this experimental investigation was to determine which portion of the ultimate strength under fast (short-time) loading can be sustained indefinitely by an eccentrically loaded reinforced-concrete column. Forty-five column tests are reported; 13 tests were made with fast loading, 12 with slow loading, and 19 with sustained loading. In addition to the type of loading, concrete strength and eccentricity of load were the major variables studies.

The test findings indicate that the ultimate strength under sustained loading is only about 10% below that for fast loading. It seems satisfactory, therefore, to base safety in ultimate strength design on the ultimate strength equations for fast static loading, which equations are substantiated by numerous previous tests.
From authors' summary

3973. Floor, W. K. G., Compression tests of columns having open cross sections, *Nat. LuchtLab. Amsterdam Rap.* S.439, 36 pp. + 28 tables + 29 figs., 1954.

Compression tests were carried out on nine different types of columns having open cross sections. The length of the specimens was so small with respect to the dimensions of the cross sections that nearly all columns failed as a result of local buckling, torsional buckling, or a combination of both.

A survey of the specimens tested is given, together with their actual dimensions.

The columns were loaded in a universal materials testing machine, the ends of the specimens resting directly against the compression plattens of the machine. The ultimate loads and the loads at which initial buckling deformations were first observed, as well as the corresponding average stresses in the cross sections of the columns, are presented. The stresses are also represented graphically.

Methods for calculating the average stresses in the cross sections corresponding to the initial buckling and ultimate loads are discussed, and diagrams to be used in such calculations are presented.

The experimentally determined average stresses in the cross sections of the columns at the initial buckling and the ultimate loads are compared with the corresponding calculated stresses.
From author's summary

3974. Lubinski, A., and Blenkarn, K. A., Buckling of tubing in pumping wells, its effects and means for controlling it, *J. Petr. Technol.* **9**, 3, 73–88, Mar. 1957.

Authors discuss an unusual and important buckling phenomenon which occurs in the tubing of oil-pumping wells. Buckling results in increased wear, higher horse-power requirements, and more frequent failures. Unusual feature of the buckling is that it occurs when the tubing is under considerable internal pressure and when the stresses are tensile throughout. It is essentially due to the tension in the sucker-rod string during the upstroke of the pump plunger. Methods of preventing the occurrence of the phenomenon are given in the paper, the most favored being the use of tension anchors. P. C. Dunne, Brazil

3975. Weingarten, V. I., The buckling of triangular or skew plates, *J. aero. Sci.* **24**, 5, p. 384, May 1957.

The problem of determining the critical elastic buckling load of a triangular plate has attracted some notice. The writer wishes to call attention to a simple solution of this problem through use of Richardson's h^2-extrapolation formula in conjunction with the finite difference technique. From author's summary

3976. Shuleshko, P., A reduction method for buckling problems of orthotropic plates, *Aero. Quart.* **8**, part 2, 145–156, May 1957.

Author endeavors to reduce the lengthy computational work connected with buckling problems of biaxial-loaded *orthotropic* plates by establishing so-called "reduction equations," by the aid of which the problems under consideration can be reduced to the problem of finding the critical load for an *isotropic* plate. A number of particular cases are treated [see AMR **9**, Rev. 3216].
C. B. Biezeno, Holland

3977. Yanowitch, M., Non-linear buckling of circular elastic plates, *Comm. pure appl. Math.* **9**, 4, 661–672, Nov. 1956.

Two cases of instability of circular elastic plates are considered, in which it is shown that buckling can take place from an initially deformed state which already requires the use of non-linear equations for an adequate description. The problems discussed are (a) a circular plate under a uniform transverse pressure, resting at its edge on a rigid support, and (b) a circular plate under a uniform compressive edge pressure in the plane of the plate, the

edge being constrained by an elastic uniformly distributed spring. The analysis is based on the Karman equations, and is carried out by a variational technique which is discussed in detail. The buckling modes are not assumed to be axisymmetrical.

B. A. Boley, USA

3978. Kollbrunner, C. F., and Herrmann, G., Influence of shear upon the stability of plates in the elastic region (in German), *Mitt. T.K.V.S.B.* 14, 38 pp., 1956.

Authors start from R. D. Mindlin's assumption [AMR **4**, Rev. 3826] that vertical filaments remain straight but do not necessarily remain normal to middle surface. They conclude that the critical load can be reduced by shear not more than up to 1% in case of simply supported rectangular plate compressed in one direction. They presume that this effect can be much more important beyond the elastic limits.

J. M. Klitchieff, Yugoslavia

3979. Bijlaard, P. P., Buckling under external pressure of cylindrical shells evenly stiffened by rings only, *J. aero. Sci.* **24**, 6, 437–447, 455, June 1957.

Technical calculations are given for determining the critical pressure for panel buckling as well as general instability of shells evenly stiffened by rings with equal spacings. The results obtained in the prescribed way for one cylinder, treated experimentally by R. C. Shankard and W. Nash, prove to be quite satisfactory. The paper requires due knowledge of former papers by the same author [e.g., AMR **6**, Rev. 2460; **7**, Revs. 1069, 1070].

C. B. Biezeno, Holland

3980. Fung, Y. C., and Sechler, E. E., Buckling of thin-walled circular cylinders under axial compression and internal pressure, *J. aero. Sci.* **24**, 5, 351–356, May 1957.

Tests on cylinders, 11.0 in. long with a 3.5-in. inside diameter, made of 24 S-H (condenser foil) aluminum alloy sheets of 0.001, 0.002, and 0.003-in. thickness, are described and results are compared with theory of Lo, Crate and Schwarz [AMR **4**, Rev. 167]. Although buckling stresses are considerably below theoretical values and show large scatter, authors state that $\Delta\sigma_{cr}$, the increment of critical stress σ_{cr} over that without internal pressure σ_{cr_o}, shows reasonable agreement with theory. Reviewer notes, however, that for σ_{cr_o} authors use values of Kanemitsu and Nojima [Galcit Thesis, 1939], whereas authors' test results are definitely lower and in better agreement with reviewer's proposals of 1946 [AMR **2**, Rev. 726]. Therefore, for small internal pressures, authors' suggested design method may be unconservative (e.g. for model No. 5, design method is unconservative over full range of test results in Fig. 2).

F. J. Plantema, Holland

3981. Lisowski, A., Buckling of cylindrical and spherical shells; model experiments (in German), *Bull. Acad. Polonaise Sci. Cl. (IV)* **5**, 2, 107–113, 1957.

Loss of stability of flat cylindrical and spherical shells, stressed by continuous constant load, is experimentally studied, and results obtained are compared with the theory. Difference lies between 10–20%.

V. Kopriva, Czechoslovakia

3982. Seide, P., Axisymmetrical buckling of circular cones under axial compression, *J. appl Mech.* **23**, 4, 625–628, Dec. 1956.

Following the approach given by Timoshenko for cylinders and spheres [see "Theory of elastic stability," McGraw-Hill Book Co., Inc., N. Y. 1936, pp. 419–497], author derives equilibrium and stress-strain relations for a frustrum of a right circular cone under axial compression. For a cone of constant thickness, the differential equations are solved for (u,w), the additional middle-surface displacement components in the direction of cone generator and in direction normal to cone wall, due to buckling. Determinantal equation for instability of cone is obtained by substitution of expressions for (u,w) into the boundary conditions. Equation is solved with Poisson's ratio equal to zero. Numerical example is worked out, but no comparison with experimental results is given. Reviewer believes that more attention should be directed toward this fundamental problem.

A. P. Boresi, USA

3983. Basler, K., The eccentrically compressed and laterally loaded prismatic strut (in German), *Schweiz. Bauztg.* **74**, 39, 587–589, Sept. 1956; **74**, 41, 627–631, Oct. 1956.

Author presents a graphical solution as well as approximate analytical solution of $y'' = M/EI$ for laterally or eccentrically loaded columns. Graphical solution gives moments and shears throughout entire member and is particularly adaptable to concentrated lateral loads. This method is a companion to Howard's circle.

M. Holt, USA

3984. Chilver, A. H., Buckling of a simple portal frame, *J. Mech. Phys. Solids* **5**, 1, 18–25, Nov. 1956.

The model portal frame under consideration consists of two columns, hinged to rigid foundations, and of two rigid triangular members which in turn are hinged to each other at the middle line of the frame. Vertical loads act symmetrically on the triangular members.

From compatibility equation and equation of static equilibrium, for symmetric and antisymmetric distortion of the frame respectively, a relation between applied load, location of load, and vertical displacement of hinge at middle line is derived, which relation is used for determining the buckling load.

The analysis is performed in order to demonstrate that the presence of initial bending effects influences the magnitude of buckling load.

E. Steneroth, Sweden

3985. Allen, H. G., The design of triangulated frameworks on an elastic basis. Parts I, II, *Civ. Engng., Lond.* **52**, 609, 313–316, Mar. 1957; **52**, 610, 436–438, Apr. 1957.

Paper presents a method of most economical calculation of triangulated frameworks. The working load and its load factor are supposed to be given, and the geometry of the structure as well as the types of sections to be used for the member tubes, double-angle, etc., are known. The initial bow of the struts is supposed to be known, but possible eccentricities at the joints are disregarded. Members are regarded to be on the point of failure when the maximum stress in them calculated on an elastic basis just attains the yield stress. The effective length of struts is determined by iteration with consideration of the elastic restraint of joints. It is demonstrated that, in the case of correct design, the ratio γ of failure load to critical load is the same for any member. The calculation is started with an assumed γ value. Stability check is executed for the cross-sectional dimensions determined by the assumed γ value. If the stiffness of the joints is found to be positive, or negative, instead of zero, the calculation is repeated at a lower or a higher value of γ. With the two results thus obtained, the final γ value is found by interpolation. For a proper γ value, all members of the truss are safe in the same degree. If, however, the effective length of struts is assessed at the routine value of $L = 0.8l$, some struts will have insufficient, while others will enjoy superfluously great, safety.

The proposed new method is not much more lengthy than the orthodox one, provided the stability of struts against buckling is checked by calculation. The neglect of tie stiffness, which the author thinks justified for other reasons too, is a substantial simplification in the calculation.

In reviewer's opinion, the paper is an interesting tentative method of the rational analysis of triangulated frameworks, It is regrettable, however, that the author takes for the limit state of failure such a state in which the load-carrying capacity of the weak cross sections has not yet been fully exploited.

P. Csonka, Hungary

3986. Murray, N. W., A method of determining an approximate value of the critical loads at which lateral buckling occurs in rigidly jointed trusses, *Proc. Instn. civ. Engrs.* **7,** 387–403, June 1957.

Paper develops a method for estimating the critical load for lateral buckling of a plane frame. Moment-distribution calculations are carried out over a limited region of a framework, beginning with a perturbing moment at a chosen node, and a stability criterion is developed corresponding to the transition from convergence of the successive approximation process. Good agreement with experiments on a Warren Girder is reported.

W. S. Hemp, England

Joints and Joining Methods

(See also Revs. 4000 and 4005)

Book—3987. Laughner, V. H., and Hargan, A. D., Handbook of fastening and joining of metal parts, New York, McGraw-Hill Book Co., Inc., 1956, vii + 622 pp. $15.

Book is divided into two major sections, the first covering the following topics in 12 chapters (432 pp.): screw and pipe threads; screws, bolts and nuts; lock nuts and washers, retaining rings; practical considerations in design of screw fastenings; riveting, setting and staking; welding with pressure; gas, arc and thermit welding; brazing and soldering; adhesives and bonded joints; collars, couplings and clutches; keys, splines and interference fits; miscellaneous assembly methods and specialty fasteners. Treatment is (deliberately) uneven because the various methods of fastening are not always closely related. Chapters on threaded fasteners cover standard types and have much tabular material, with some guidance to their proper utilization, whereas sections on welding and brazing go much further into descriptions of principles, equipment, advantages and limitations. Second major section is the "Supplement" (180 pp.), containing 1500 "ideas for fastening and joining" in diagram and chart form, as a guide for designers.

Book should be very useful to designers and production engineers, since it assembles under one cover much material scattered throughout standard reference works and the technical literature. Reviewer has noted a few minor errors, such as the statement that (p. 222) "...carbon has negative resistance..." (instead of negative temperature coefficient of resistance), and an obvious omission in a diagram on p. 581. J. L. Lubkin, USA

3988. Easton, F. M., Lewis, E. M., and Wright, D. T., Some notes on the use of high preload bolts in the United Kingdom, *Struct. Engr.* **35,** 5, 167–175, May 1957.

3989. Cornish, R. J., Analysing displacements of plane pin-jointed frames, *Civ. Engng., Lond.* **51,** 605, 1231–1233, Nov. 1956.

3990. Monroe, R. E., and Martin, D. C., Welding of molybdenum heat exchangers, *Welding J.* **35,** 12, 1222–1225, Dec. 1956.

The feasibility of producing complex welded components in currently available arc-cast molybdenum was demonstrated by the construction of simulated heat exchangers. Assemblies containing 52 tubes welded into a header sheet were completed without any failures occurring as a result of room-temperature brittleness of the welds. Identical welds were not always obtained because of factors which are apparently associated with the cone-arc welding process. The arc column does not appear to rotate as suggested in the original cone-arc theory. From authors' summary

3991. Farrell, W. J., and Solomon, J. L., A new concept for control of resistance-welding machines, *Welding J.* **26,** 4, 356–362, Apr. 1957.

3992. Stark, H. J., and Glickman, M., Adhesive bonding of polystyrene foam for naval service, *J. Amer. Soc. nav. Engrs.* **68,** 4, 739–742, Nov. 1956.

Structures

(See also Revs. 3919, 3938, 3942, 3962, 3963, 3968, 3984, 3985, 3986, 3987, 4012, 4039, 4040, 4042, 4096, 4097, 4176, 4208, 4221)

3993. Humphreys, R., Torsional properties of prestressed concrete, *Struct. Engr.* **35,** 6, 213–224, June 1957.

Paper reports on a series of torsion tests on prestressed rectangular beams, with side-to-width ratios from one to four. Compressive end stresses were concentrically applied and varied from zero to 6000 psi. The ultimate torsional stress for the prestressed beams is compared with plain concrete beams. The stress is shown as a linear function of the applied prestress and the maximum tensile stress of the concrete. The function is derived based on the principal stress theory of failure. Recommended design formulas and constants are given for the maximum twisting moment of rectangular beams concentrically and eccentrically prestressed.

I. A. Benjamin, USA

3994. Avoiding friction on curved prestressing cables, *Concr. constr. Engng.* **52,** 3, 109–112, Mar. 1957.

3995. Symposium on the application of plasticity in the calculation of reinforced concrete structures, Buenos Aires, 1953; Buenos Aires, El Ateneo, Publisher, 1955, 3 papers, 122 pp.

3996. Whitney, C. S., and Cohen, E., Guide for ultimate strength design of reinforced concrete, *J. Amer. Concr. Inst.* **28,** 5, 455–490, Nov. 1956.

3997. Matheson, J. A. L., The degree of redundancy of plane frameworks, *Civ. Engng., Lond.* **52,** 612, 655–656, June 1957.

3998. Turkin, K. D., Calculation of a cylindrical shell in constrained torsion on the basis of a new hypothesis (in Russian), "Calculation of three-dimensional frameworks," no. 3, Moscow, State Publ. Est. for Lit. on Civ. Eng. and Archit., 1955, 265–284; *Ref. Zh. Mekh.* 1956, Rev. 4746.

The approximate calculation is discussed of a thin-walled shell with a rigid contour cross section. One end of the shell is assumed to be constrained, and the other end freely supported.

The author assumes, with an accuracy equal to the value of the constant additive, that the ratio of the two components of shearing deformation in the median surface of the shell is equal to the product of two unknown parameters, each of which is a function of only one coordinate. These parameters determine, for a given center of torsion, the tangential and normal stresses in the cross section of the shell. The unknown parameters and the coordinates of the center of torsion are determined from integral equations for the equilibrium of the external and internal forces and the condition of minimum potential energy. The latter condition leads to the variational problem.

Examples are discussed of the analysis of shells with open and closed section contours in which the influence of the length of the shell on the position of the center of torsion, and on the character of the distribution of the normal and tangent stresses in the cross section of the shell is examined.

Courtesy Referativnyi Zhurnal V. A. Mar'in, USSR
Translation, courtesy Ministry of Supply, England

3999. Novinsky, Yu., Torsion of a thin-walled box beam with a discontinuous conical outer surface (in Russian), *Bull. Polsk. Akad. Nauk Otd. IV* **2,** 2, 65–70, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4747.

The constrained torsion of a thin-walled conical box beam with an open cross-section contour is examined. It is assumed that the cross sections of the beam are not deformed in their own planes and the conicity of the conical surface is small.

Author has arrived at an approximate solution of the problem for a thin-walled box beam the wall thickness of which varies along the generatrix of the cone according to the equation

$$\delta = \delta_0 \frac{l}{l - t}$$

in which l is entire length of the generating line of the conical surface and t distance from the cross section in question to the supported cross section (where the thickness $\delta = \delta_0$) along the generating line.

The approximate solution is founded on the assumption that the displacement of the cross section $\zeta(s,t)$ can be represented in the form $\zeta(s,t) = \zeta(s)\,\zeta(t)$. The final equations have the form usual for the theory of thin-walled box beams, and can be more simply obtained if the displacement of the cross sections is determined from the condition of least deformation in shear $y\,s\,t$, as has been done in the theory of thin-walled box beams by V. Z. Vlasov ["Thin-walled elastic box beams," Gosstroyizdat, 1940].

Thin-walled conical box beams with closed contours of the cross section are discussed by B. P. Tasibulya [*Trudi VVIA, im. N. E. Zhukovskogo* 1947, (253)], and the abstractor [*Trudi CAHI* 1947, (650)].

L. I. Balabukh, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4000. Snitko, N. K., Strength and stability calculations for girders with rigid joints (in Russian), "Calculation of strength, stability, rigidity and oscillation," Moscow, Mashgiz, 1955, 199–205; *Ref. Zh. Mekh.* 1956, Rev. 4757.

The following calculation procedure is suggested for girders or trusses with rigid joints: (1) The longitudinal forces in the truss members and the angular rotations of these elements are determined in first approximation, starting from a hinge-jointed framework. (2) Equations for the truss with rigid joints are derived by the method of deformation or the method of forces, and the approximate values obtained for the angular rotations are put into these equations. (3) After the moments at the joints have been determined, the accurate values of the angular rotation, etc., can be calculated.

This calculation sequence is illustrated by two examples. The first example concerns the symmetrical deformation of the simplest framework, consisting of two bars and loaded by a concentrated force at the joint. For such a truss, however, the fundamental form of loss of stability will be obliquely symmetrical.

In the second example, the fundamental form of loss of stability, giving the lowest critical value, is likewise obliquely symmetrical. Further, calculating the stability of the truss, author obtains an elastic bending value for one of the truss bars of $\lambda = 90$ and determines the critical force, introducing the referred modulus T. On the other hand, (omission) has been determined on the assumption that the E moduli of all frame bars are identical.

Courtesy Referativnyi Zhurnal V. V. Bolotin, USSR
Translation, courtesy Ministry of Supply, England

4001. Hendry, A. W., and Jaeger, L. B., The analysis of certain interconnected arch systems, *Struct. Engr.* **35**, 7, 256–260, July 1957.

In previous papers [AMR **9**, Revs. 3924 and 3925], authors have elaborated a theory for interconnected beam systems of various types. Purpose of present paper is to demonstrate application of method to interconnected two-pinned sinusoidal arch systems in which torsional effects may be omitted and in which cross girders possess negligible flexural rigidity as regards bending moments in horizontal plane. It is immaterial whether cross-girder loads are transmitted to ribs through spandrel columns or whether cross girders are directly connected to ribs. These assumptions would be fairly closely met in a system of steel arch ribs and cross girders of I section. It is also observed that although the analysis is for a rib of sinuosidal shape it will apply with reasonable accuracy to a parabolic arch.

As well as providing a distribution theory, the method provides a new and extremely simple method for the analysis of this type of arch rib.

From the authors' summary by W. D. Jordan, USA

4002. Sokolovskii, V. V., Forms of stability for arcs and semi-arcs (in Russian), *Prikl. Mat. Mekh.* **20**, 1, 73–86, Jan./Feb. 1956.

This plane problem in soil mechanics is based on the assumption that soil is a plastic material in which slip or yield occurs when stresses satisfy the Coulomb equation and the equations of equilbrium. The state when the stresses satisfy the Coulomb equation the author calls "the limiting state of equilibrium." Beyond this state an earthy structure becomes unstable. The author considers earthy arcs and semi-arcs loaded by their own weight and finds their contours in the limiting state. Some of the results are in a closed form, but in most cases numerical methods are necessary.

T. Leser, USA

4003. Hendry, A. W., and Jaegar, L. G., The analysis of certain interconnected skew-bridge girders, *Proc. Instn. civ. Engrs.* **6**, 79–106, Jan. 1957.

Skew bridges with three or four longitudinal girders of negligible torsional stiffness are studied by author's method [AMR **9**, Rev. 3925; **10**, Rev. 1078]. The solution for bridges with more than four girders is discussed and influence of varying skew angle is investigated. A comparison between experimental (models) and theoretical results shows good agreement.

E. P. Villarreal, Argentina

4004. A laminated timber roof structure, *Timber Technol.* **64**, 2209, 577–579, Nov. 1956.

"The most ambitious use of laminated timber," uniquely demonstrating the versatility of wood as a structural medium, is demonstrated in the new assembly hall of the Rangoon University in Burma, designed to withstand 90-mph winds. The laminated "marine turtle" shell over an area of approximately 90 ft × 150 ft and weighing 140 tons is supported by two arched latticed steel frames of 66-ft span. The shell consists of five laminations of butt-jointed teak boards, the first 7/8 in. thick and the remaining ones 5/8 in. thick, set in resorcinol-resin glue, with the direction of the boards changing from longitudinal to transverse to two opposite diagonal, and to longitudinal direction.

E. G. Stern, USA

4005. Fox, S. P., An investigation into the effects of certain variables in scarf-jointed timber laminations, *Forest. Prod. J.* **6**, 10, 428–437, Oct. 1956.

From 950 tests on the effect of scarf joints and notches on the tension-parallel-to-grain strength of Douglas fir, information was obtained on (1) effect of change in cross-sectional area of scarf-jointed and nonjointed specimens, (2) strength ratios of specimens with scarf joints of different dimensions versus nonjointed specimens, (3) effect of removal of end steps of hooked scarf joints, (4) effect of notching.

The following conclusions can be advanced: Change in cross-sectional area had no significant effect. Notches of scarfs as well as notches in nonjointed specimens created stress concentrations. Depth of notch and strength ratio are related in a curvilinear manner, with increase in notch depth resulting in decrease in effectiveness of specimen. Removal of the end-step notch resulted in increase of the strength ratio.

E. G. Stern, USA

4006. Ketchum, V., New developments in engineered wood design and construction, ASTM Second Pacific Area Nat. Meet., Sept. 17-21, 1956. Pap. 89.

Advantages and disadvantages of timber construction are discussed. The accomplishments of the American Institute of Timber Construction and the various inspection services are cited. Recent literature on various types of timber structures is reviewed in a general manner. E. G. Stern, USA

4007. Dorey, D. B., and Schriever, W. R., Structural test of a house under simulated wind and snow loads, ASTM Second Pacific Area Nat. Meet., Sept. 17-21, 1956. Pap. 112.

A typical framed 24 × 36-ft one-story house with pitched roof, fastened to a concrete-block foundation with anchor bolts, was subjected to tests on its strength and stiffness by applying inward and outward thrusts with double-acting hydraulic rams fastened to a reaction framework erected over the house to be tested. The loading included internal suction and pressure wind loads; one-half design snow load and wind loads; larger snow loads.

The tests indicated that wind loads simulating 90 and 120-mph velocities were well withstood by the house, and snow loads up to 143% of the 50 lb/sq ft design load could be resisted.

Such tests on full-size structures are likely to yield a maximum amount of information if the structure is especially designed for test purposes in order to eliminate variables which are difficult to evaluate and can be eliminated under controlled conditions.

E. G. Stern, USA

4008. Gould, J. J., and Degenkolb, H. J., Building design for lateral forces, ASTM Second Pacific Area Nat. Meet., Sept. 17-21, 1956. Pap. no. 116.

The effectiveness is discussed of diaphragm panels to resist wind and earthquake forces. The degree of flexibility of the diaphragms is decisive on the resistance of a structure to these forces. Diaphragms should be as rigid as possible to resist wind forces; however, they should have some flexibility to resist seismic and shock loadings. Hence, the selection of the structural materials to be used for exposed structures is to be given prime consideration. E. G. Stern, USA

4009. Moehler, K., Fundamentals and potentialities of nailed structures, *Holz als Rob- und Werkstoff* **13**, 10, 388-397, Oct. 1955.

Basic considerations in the design of nailed structures are discussed, including the effectiveness of nails in double shear under static and dynamic load applications.

Use of high-carbon-steel nails, square fluted nails, and double-shank nails, predrilling, and use of plywood and steel splice plates provide promising potentialities in improving the design and erection of nailed structures. E. G. Stern, USA

4010. Broglio, L., Static analysis of swept wing by the balance method, *Universita de Roma Scuola di Ingegneria Aeronautica, Istituto de Costruzioni Aeronautiche Tech. Rep.* 3, 88 pp., Nov. 1955.

The swept-wing structure considered in this paper is a cantilever box girder with rectangular cross section, reinforced by strip caps at the corners of the cross section and by stringers continuously and uniformly distributed along the breadth of the upper and lower sheets. The ribs are assumed to run parallel to the vertical plane of symmetry of the airplane. The external loading consists of vertical loads distributed along the front and rear spars.

The solution of the problem is obtained by using the balance method developed and explained in detail in two previous papers by the author [Repts. no. 1 and 2 of the series; AMR **9**, Rev. 3241]. According to this method of analysis, besides the external loading, two self-balanced load systems are considered at each rib: moments acting in the plane of the rib and warping forces acting normally to this plane. The elastic displacements are expressed by equations containing two groups of parameters: those which define the rigid motion of the rib and others, called "distortion parameters," defining the flexibility of the rib in its plane and the warping of the rib.

The balance method leads to equations containing only distortion parameters (as unknowns) and self balancing systems (as known terms); these equations can be solved by successive approximations, since the convergence is insured according to Saint Venant's principle

Numerical results are represented by diagrams for a box girder with constant cross-section area, the sweep angle varying from 0 to 60 degrees, as well as for box girders with linearly or exponentially varying cross-section area.

Compared with conventional methods, the equations of the balance method are simpler; most of the computations can be carried out by inexperienced personnel and can easily be programmed for computing machines. E. Seydel, Germany

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 3924, 3949, 3956, 3971, 3995, 4048, 4053, 4145)

Book—4011. Eirich, F. R., editor, Rheology. Vol. I, Theory and applications, New York, Academic Press, Inc., Oct. 1956, 761 pp., $20.

Book, first of three volumes, presents most of the fundamental material on which rheology is based. Emphasis is placed on theoretical aspects, although most chapters include references to experimental methods and results. Authors are all noted authorities in their field.

The general plan of the work is outlined in a concise introductory chapter "Introduction to rheological concepts" by F. R. Eirich. The following comments give a short survey of contents. The 16 expository chapters of the book, which in the original follow a loose sequence, have been arrayed under 4 headings ranging from fundamental theory of solids and liquids in general to studies of particular properties of materials. This subdivision, which, of course, is somewhat arbitrary, shows the inherent systematic structure of the work.

I *Phenomenology.* Behavior of solids in general is discussed in several fundamental articles which lead all the way from theoretical principles to practical applications: "Phenomenological macrorheology" by M. Reiner; "Large elastic deformations" by R. S. Rivlin; "Finite plastic deformation" by W. Prager. The mechanics of general types of flow is given in "Non-Newtonian flow of liquids and solids" by J. G. Oldroyd. Particular classes of materials are discussed in "Stress-strain relations in the plastic range of metals, Experiments and basic concepts" by D. C. Drucker, and "Dynamics of viscoelastic behavior" by T. Alfrey, Jr. and E. F. Gurnee. Experimental and theoretical foundations of the behavior of rheological coefficients of materials, as used in phenomenological theories, are given by R. B. Dow in "Some rheological properties under high pressure."

II *Dislocation theory of rheological properties* is discussed in 3 articles; "Mechanical properties and imperfections in crystals" by G. J. Dienes, "Dislocations in crystal lattices" by J. M. Burgers and G. W. Burgers, and "Mechanical properties of metals" by J. Fleeman and G. J. Dienes.

III *Molecular and rate theory of viscosity* is given in "Theories of viscosity" by A. Bondi, "The statistical and mechanical theory of irreversible processes in solutions of macromolecules" by J. Riseman and J. G. Kirkwood, "The viscosity of colloidal suspensions and macromolecular solutions" by H. L. Frisch and R. Simha, and "Viscosity relationships for polymers in bulk and in concentrated solutions" by T. G. Fox, S. Gratsch, and S. Loshaek.

IV Finally, there is a rather complete survey on *Optical effects* in "Streaming and stress birefringence" by A. Peterlin, and a short summary of *Acoustical effects* in "Acoustics and the liquid state" by R. B. Lindsay.

A list of symbols and nomenclature after each chapter and extensive author and subject indices increase the value of the volume for reference purposes. General presentation is excellent. Some of the theories which are discussed may in time be extended, but will hardly be substituted by new developments. Therefore in spite of the present rapid growth of rheology, this volume will be used for a long time to come as a textbook by the research worker who wants to penetrate into the field of rheology and as a reference book for those who are already actively engaged in the field. In conclusion it is to be strongly recommended to all those whose scientific activities lead to problems of rheology.

B. Gross, Brazil

Book—4012. Neal, B. G., The plastic methods of structural analysis, New York, John Wiley & Sons, Inc., 1957, xi + 353 pp. $7.50.

Book is an attempt to review theories of limit design for frame works in a form suitable as a text for a course to "constitute an important addition to an undergraduate teaching curriculum." First three chapters serve as introduction and give basic principles and physical background for formation of plastic hinges as well as examples of plastic collapse of beams and simple frame works. Partial and over-complete collapse are also discussed and elucidated by examples. Fourth chapter gives general methods for plastic design. These methods are (a) trial and error (J. F. Baker, 1949); (b) combining collapse mechanisms (B. G. Neal and P. S. Symonds, 1952; AMR **5**, Rev. 2598); (c) plastic moment distribution M. R. Horne, 1954; AMR **8**, Rev. 72); (d) other methods. Full account is given of methods (a), (b), (c), whereas (d) are merely mentioned with emphasis on their merits and shortcomings.

Rest of book is devoted to estimate of deflections, factors affecting fully plastic moments and minimum weight design. A special chapter treats variable repeated loading, so-called shakedown problems, resulting either in incremental collapse or in alternating plasticity. These problems are treated with methods (a) or (b) above.

All chapters contain references to literature, all significant though perhaps not complete. References and worked examples will help reader to form a fairly complete picture of subject. Numerous exercises with answers should also be helpful to students. In four appendices, plastic moduli of British Standard Beams and proofs of certain general theorems are given. In reviewer's opinion, this clear and logical presentation of the subject is a most valuable addition to our engineering textbooks by an eminent contributor to this field of research.

F. K. G. Odqvist, Sweden

4013. Hill, R., On the problem of uniqueness in the theory of a rigid-plastic solid—I, *J. Mech. Phys. Solids* **4**, 4, 247-255, 1956.

This is the first of three papers that mark an important advance in the theory of work-hardening plastic solids. For elastic, plastic solids of the perfectly plastic as well as the work-hardening type, properly set boundary-value problems, the uniqueness of their solutions, and the associated extremum principles have been exhaustively discussed in the technical literature of the last decade. The corresponding discussion of rigid, perfectly plastic solids has yielded valuable results, but important questions remain unanswered. Prior to the present papers, however, rigid, work-hardening solids had not yet been systematically treated from this point of view. In a typical boundary-value problem for an elastic, plastic solid, the mechanical state is supposed to be known throughout the considered body, the rates of traction or displacement are prescribed over the entire surface, and the rates of stress and displacement are to be determined throughout the body. The corresponding problem for a rigid, perfectly plastic solid involves the tractions and stresses themselves and not their rates. Under these boundary conditions the fields of stress rate and velocity in an elastic, plastic solid are unique; in a rigid, perfectly plastic solid, however, the stress field is unique only outside the region that is rigid according to all solutions, and the velocity field may not be unique at all.

For a rigid, work-hardening solid, two types of boundary-value problem must be considered. During plastic flow under continuously varying surface tractions or surface displacements, the instantaneous state of stress is known from the mechanical history of the body, and the problem reduces to the determination of the instantaneous rates of stress and displacement in the interior from the instantaneous rates of traction or displacement on the surface. Clearly, this first type of problem is closely related to the classical boundary-value problem for an elastic, work-hardening solid. Assuming yield function and plastic potential to be identical at each point of the considered body, stipulating continuous velocity fields, and restricting himself to a first-order theory that neglects changes in geometry, author shows that the velocity field is unique while the stress-rate field may lack uniqueness even in the region of plastic deformation. The extremum principles associated with this boundary-value problem are established.

A second type of problem arises when the considered body is unloaded after a nonhomogeneous state of hardening has been produced, and then subjected to a different type of loading. In the initial stages of the new loading program, the body will behave in a rigid manner, and the instant must be determined at which plastic deformation sets in. This is a problem of limit analysis of the type encountered in the theory of rigid, perfectly plastic solids. In this theory, it is shown that the velocity field need not be unique. For the rigid, work-hardening solid, however, a unique velocity field is specified by the requirement that there must exist an equilibrium distribution of stress rate compatible with the strain-rate field and the known rate of surface traction. As in the theory of rigid, perfectly plastic solids, the stress field is found to be unique in the region of plastic deformation.

Brief concluding sections contain remarks concerning velocity discontinuities and the possibility of obtaining a unique velocity field in a rigid, perfectly plastic solid by considering this solid as a limiting case of a rigid, work-hardening solid.

W. Prager, USA

4014. Hill, R., On the problem of uniqueness in the theory of a rigid-plastic solid—II, *J. Mech. Phys. Solids* **5**, 1, 1-8, 1956.

In this second paper, torsion of a prismatic bar consisting of a rigid, work-hardening material is used to illustrate the results obtained in the first paper. In particular, the case of a hollow cross section with uniform wall thickness and smooth boundaries is discussed.

W. Prager, USA

4015. Hill, R., On the problem of uniqueness in the theory of a rigid-plastic solid—III, *J. Mech. Phys. Solids* **5**, 3, 153-161, 1957.

The preceding papers were concerned with a first-order theory that neglects all changes of geometry. The present paper develops a second-order theory that accounts for these changes to the first order. Two types of stress boundary conditions are considered: the rate of the nominal surface traction based on the configuration at the initial instant is prescribed, or a uniform fluid pressure is supposed to be applied to that part of the surface where the boundary conditions are on stress. A sufficient criterion for uniqueness is derived; for a specific problem, this yields a critical rate of work-hardening above which the velocity field must be unique while it may lack uniqueness below this critical rate.

The conventional tension, compression, and torsion tests are discussed as illustrations of the general principles.

W. Prager, USA

4016. Jaoul, B., Study of the tensile test curve in plastic deformation (in French), *J. Mech. Phys. Solids* **5**, 2, 95–114, Mar. 1957.

In this interesting paper, author describes his experimental investigations of the two fundamental problems of plastic deformation of metals: The shape of stress-strain curves, and the mechanisms of deformation along these curves. He covers a whole range of metals including face- and body-centered cubic and hexagonal structures. He deals with polycrystalline metals as well as with single crystals.

The author proposes to describe a stress-strain curve of metals by using two parabolas instead of one as proposed by Ludwik ["Elemente der Technologishen Mechanik, Berlin, 1909] ($\sigma = \sigma_0 + A\epsilon^m$). He found that two parabolas can describe quite accurately an experimental stress-strain curve. He discusses at length the relation of the parameters of parabolas to the physical conditions of metals such as grain size, temperature of test, temperature of annealing, etc. Author divides the stress-strain curve into four parts and ascribes to each of them a different mechanism of deformation. These domains are:

(1) Pseudo-elastic deformation;
(2) Domain of intergranular hardening in polycrystals and corresponding easy glide region in single crystals;
(3) Domain of a linear intracrystalline strain-hardening; and
(4) Domain of large deformations.

These four stages are not necessarily all present during deformation of a specific metal.

In the reviewer's opinion, the generality of presentation of the relation of stress-strain curve as two parabolas at best is restricted to a specific path of deformation when temperature and rate of straining is constant during the test; otherwise, it would represent another form of equation of state, the nonexistence of which was proved by many experiments.

The reviewer would also like to refer to the paper by P. Feltham and J. D. Meakin [*Phil. Mag. (8)* **2**, 13, p. 105, Jan. 1957], not mentioned in the reviewed paper, and dealing with the mechanism of plastic deformation for copper. The results described in second cited paper support the ideas expressed in the reviewed paper.

W. Sylwestrowicz, USA

4017. Higuchi, M., The transitional rate of straining corresponding to a relaxation time, *Rep. Res. Inst. appl. Mech, Kyushu Univ.* **4**, 15, 93–98. Jan. 1956.

The relationship

$$\text{Transitional strain rate} = \frac{\text{Elastic strain limit}}{\text{Relaxation time}}$$

is presented to establish the concept "correspondence of a transitional strain rate to a relaxation time" which thus far has been used vaguely, and it is shown that the predicted temperature dependence of the rate agrees with the tendency having been recognized by several investigators.

The order of magnitude of the plastic strain limit and that of the elastic strain limit of the employed model are calculated with the data of some textile materials and estimated to be 10^{-1} and 10^{-2}, respectively.

Refering to the limiting breaking velocity and the critical impact velocity, writer gives his view that neither has direct relation to the transition phenomenon here considered.

From author's summary

4018. Venkatraman, B., and Hodge, P. G., Jr., Creep behavior of circular plates, *PIBAL Rep.* 369, 24 pp. + 11 figs., Apr. 1957.

An analysis of creep in circular plates under the action of uniformly distributed lateral loads is presented. The creep law used is based upon a flow rule associated with a condition of maximum shearing stress. It is assumed that steady creep conditions prevail and that the creep rate is equal to a function of moment multiplied by a function of time. The method is applied to plates with simply supported and clamped edges. Closed form solutions for moments and creep deformations are presented.

From authors' summary by F. K. G. Odqvist, Sweden

4019. Chudzikiewicz, A., Concrete creep in prestressed beam structures (in Polish), *Rozpravvy Inż.* **4**, 2, 227–287, 1956.

The influence of creep of concrete on the properties of structures, on the basis of Dishinger's linear theory, is analyzed. A theory of compressed systems, statically determinate and indeterminate, with free and included cables is presented. Solutions in the case of permanent load, concrete shrinkage, and support sinking are obtained. Approximate solutions are obtained in the form of power series. Criteria for the convergence of the solutions and the degree of accuracy obtained are discussed. The calculations are illustrated by numerical examples.

Z. Bychawski, Poland

4020. Ziegler, H., Thermodynamics and rheological problems (in German), *Ing.-Arch.* **25**, 1, 58–70, 1957.

In the domain of mechanics the viscoelastic analogy by T. Alfrey and its generalization can be proved only under certain specific assumptions, but if the basic rheologic equations between the deformations and forces are linear, the necessary relations can be obtained by applying Onsager's reciprocity equations of the theory of irreversible processes to the behavior of bodies with separable elastic and nonelastic deformations under the influence of forces. The existence of a velocity and of a stress potential for linear Newtonian and Maxwellian bodies can be established, and through a plausible generalization of the reciprocity relations the viscoelastic analogy can be extended to bodies with nonlinear rheologic properties. It can be proved then that the velocity potential and the complementary potential of stresses are single-valued functions and that equipotential surfaces in both spaces are concave on the side of the origin. If the Prandtl-Reussian body can be taken as a limiting case of a sequence of nonlinear Newtonian bodies, for which the viscoelastic analogy holds, the Mises-Prager relation for the deformation velocities $\dot{x}_k^u = \lambda \cdot \partial F / \partial X_k$ can be established, and the assumption that the yielding limits surface $F(X_i) = c$ in the stress space is convex becomes even more plausible.

A. Kuhelj, Yugoslavia

4021. Scheidegger, A. E., Rheology of the earth: the basic problem of geodynamics, *Canad. J. Phys.* **35**, 4, 383–397, Apr. 1957.

A discussion is given of the data which are available to provide information on the rheological behavior of the earth's mantle and crust. It is shown that a fundamental distinction has to be made between stress durations that are "short" (up to 4 hours), "intermediate" (4 hours to 15,000 years), and "long" (longer than 15,000 years). For short durations, the behavior of the earth is well known from the results of seismological investigations. However, these results should not be applied directly to the longer time durations. For intermediate time durations, the earth shows an elastic aftereffect. One obtains a value for the (Kelvin) viscosity if it is assumed that the damping of the variation of latitude is caused by a Kelvin effect. The same (Kelvin) viscosity is arrived at if the strain rebound characteristics of earthquake aftershock sequences are also interpreted in terms of an elastic aftereffect. For stresses of long duration, some information may be obtained from the uplift of Fennoscandia. It appears that viscous creep is the prevailing phenomenon. If this information is combined with some further considerations, indications are that the earth behaves like a Bingham body. Then, the fact that oro-

genetic phenomena are concentrated in narrow bands may be due to the existence of solutions of the Bingham equation exhibiting rheological instability. From author's summary

4022. Melton, L. L., Rheological measurements of non-Newtonian fluids, *J. Petr. Technol.* **9,** 7, 196–201, July 1957.

4023. Radok, J. R. M., Visco-elastic stress analysis, *Quart. appl. Math.* **15,** 2, 198–202, July 1957.

E. H. Lee [AMR **9,** Rev. 450] has discussed the use of Laplace transform techniques in the analysis of quasi-static problems of linear viscoelasticity. In any particular case, Lee's methods involve the concept of an associated elastic problem (whose solution is supposed known) that corresponds formally to the Laplace transform of the viscoelastic problem. The application is therefore restricted to the general class of problems with boundary conditions admitting this operation. The purpose of the present paper is to show that this restriction may be avoided through more general analysis.

Author shows that the elastic and viscoelastic solutions of a given boundary-value problem are related to each other through functional equations for the quantities specifying the solutions. If the elastic solution of the boundary-value problem is known, then these functional equations are given by expressing the elastic constants in this solution in terms of the differential time-operators in the general, isotropic, viscoelastic, stress-strain law. In many cases, these functional equations are ordinary differential equations in time whose solutions for the given initial conditions make up a viscoelastic solution satisfying the same boundary conditions as the elastic solution. If these functional equations are solved by the use of Laplace transform techniques, then the later stages of obtaining the viscoelastic solution coincide with Lee's methods (loc. cit.). However, the establishment of the independence of the use of Laplace transform techniques from the associated elastic problem considerably widens the range of application of these techniques.

H. G. Hopkins, England

Failure, Mechanics of Solid State

(See also Rev. 3939)

Book—4024. Goldman, J. E., edited by, The science of engineering materials, New York, John Wiley and Sons, Inc., 1957, xv + 528 pp. $12.

In the XIXth century the engineer could understand as much as anybody about the background of his work. Today he has to design equipment for industrial processes (chemical, electronic, nuclear, etc.) of which the underlying principles are often above his head; more and more frequently he is just a high-class technician who has the know-how but not the know-why. Much of this is unavoidable, a direct consequence of specialization and of the industrial gold-rush on the fields opened up by J. J. Thomson, Rutherford, Röntgen, Laue, and other physicists around the turn of the century; much, however, is due to the fact that the engineer's education in physics at some schools is half a century behind the times. Naturally, there is a strong movement to correct this deficiency; the main purpose of the present volume is to point out what ought to be done. Incidentally, it also points out why it cannot be done within the framework of the usual four-year curriculum.

The field covered by the university curriculum in engineering is far wider than that in physics. The student of physics is expected to concentrate upon the main points until he has understood them clearly enough; the most important result of his studies is not so much the acquisition of some knowledge of physics as a good training in understanding complex conceptual situations. With this, he can easily assimilate later new chapters of science or technology. The engineer, on the other hand, has to learn in his four years at the university far more than he can digest; unless he is outstanding, he may emerge with a permanently impaired mental digestive power, a feeling of confusion and diffidence, and a consequent lack of adaptability. The teacher of engineering cannot read the chapter titles of the present volume without a bitter smile; he knows that, after a thorough course in physics in the freshman and sophomore years, the level of knowledge of the senior student is usually between the first and the second laws of thermodynamics: all but the poorest remember the first, none but the best the second. This being so, the question is whether any further addition to the four-year curriculum, however vitally important, would do more good than harm. Can an excellent teacher explain, for instance, the atomic constitution of matter and the origin of the interatomic forces so brilliantly that the student really understands the salient points without too much mental strain? Is learning physics a mental storage process where the skill of the cargo-master can work wonders, or is it like learning to play the violin where even the greatest of teachers cannot relieve the student of the need for long and hard practice? The experience of this reviewer has convinced him that it is essentially a matter of "practicing": that the art of the teacher cannot, and should not, save the student long and hard thinking. The duty of the teacher is not only to stimulate the student to thinking, but also to provide him with time for thinking.

This conclusion is supported by a group of chapters in the present volume on "Structure of atoms and atomic aggregates," "The metallic state," "Electron theory of alloys and elastic properties," and "Phase transformations and mechanical properties," by J. Bardeen, W. Bitler, J. E. Goldman, R. Smoluchowski, H. Jones, and T. A. Read. The first of these chapters treats the Bohr theory, quantum mechanics–including the Schrödinger equation and its solution for the hydrogen atom–, the electronic structure of the atom, the periodic system, and the nature of the chemical bond, all on 21 pages. Scientifically and didactically it could not have been done much better; yet the reviewer is not quite sure whether the authors have meant it seriously or as a practical joke in response to an impossible demand. The situation is not so extreme but fairly similar with the reports on the metallic state on 24 pages of text, on the electron theory of alloy formation and elastic properties on 14 pages, or on phase transformations and mechanical properties on 20 pages. In view of the quality of these contributions, they can be regarded as sufficient proof that their subjects cannot be treated profitably within the present framework of the engineering curriculum.

Another group of chapters belongs to an entirely different category. They concern subjects of a more descriptive nature, and the space given to them is far more extensive. To this group belong chapters on magnetism (by J. E. Goldman and R. M. Bozorth), on semiconductors (by K. Lark-Horovitz, V. A. Anderson, E. M. Conwell, and W. J. Leivo), and on cement (by S. Brunauer). These are the most useful parts of the book; they give excellent opportunities to the nonspecialist to get acquainted with their subjects from authoritative accounts on a high level. Chapters on high polymers and on glass (by T. Alfrey, Jr., and T. H. Davies) are too brief to give much to many readers. Stimulating accounts by Harvey Brooks on "Accomplishments and limitations of solid-state theory" and by J. Bardeen on "Crystal imperfections" will be enjoyed by many, though they are hardly meant for the average interested engineer.

A third group of chapters deals with dislocations (3 chapters) and with surface phenomena. Some of these are neither as balanced nor as authoritative as accounts written for uncritical nonspecialists ought to be. In the chapter on surface phenomena, the Curie-Wulff thermodynamic theory of crystal habit is treated in detail without any reference to the decisive developments in the theory of crystal growth in the XXth century. The same chapter

contains a brief and inaccurate account of dry friction in which the Bowden-Tabor mechanism of plastic contacts, applicable to the case of "seizing" between ductile metals, is stated to represent the general mechanism of dry friction, although most cases of friction in everyday life occur between materials (stones, glass, wood, "plastics," paper, textiles, etc.) which are incapable of the plastic indentation, welding, and shearing assumed in the plastic-contact theory. The correct theory for the case of no seizure, due essentially to Lord Rayleigh, is not mentioned.

E. O. Orowan, USA

4025. Read, W. T., Jr., Dislocation theory of plastic bending, *Acta Metall.* **5,** 2, 83-88, Feb. 1957.

Author derives expression for the macroscopic stresses in a bent crystal in terms of arrays of dislocations within the crystal. Analysis is made of the situations where the flow stress in tension equals either the stress necessary to generate dislocations or the stress necessary to move dislocations. Since these lead to different behavior in bending, it is shown that materials with the same stress-strain curves in tension will give different curves in bending. Experimental tests are proposed to indicate whether the yield stress is moving or generating dislocations.

H. I. Fusfeld, USA

4026. Archard, J. F., and Hirst, W., An examination of a mild wear process, *Proc. roy. Soc. Lond. (A)* **238,** 1215, 515-528, Jan. 1957.

This paper describes a detailed study made of the wear of hardened high-speed steel rubbing on itself under relatively light loads. Radioactive tracers, optical microscopy, and other methods of surface examination were used. During the early stages of rubbing the main observable process was that of metallic welding and subsequent transfer of material between the rubbing surfaces. In the present experiments, under mild wear conditions the load remains distributed upon many regions of contact. As rubbing proceeds, the wear rate increases but the scale of size of the wear process decreases. Eventually for well run-in surfaces the wear particles may be as small as a hundred angstroms. The rubbing surfaces are then very smooth and the heights of the surface features are generally less than those of the aggregates of loose wear particles which are present on the surfaces. At this stage it is the loose debris which plays the predominant part in determining the character and rate of wear.

From authors' summary by W. O. Richmond, USA

4027. Hoenig, S. A., Meteoric dust erosion problem and its effect on the earth satellite, *Aero. Engng. Rev.* **16,** 7, 37-43, July 1957.

This survey article states that importance of dust erosion on an earth satellite depends on the size distribution, frequency of encounter for each size, and the relative velocity between the particles and the earth satellite. Estimates of size, frequency of occurrence, and velocity depend on observations of those dust particles that enter the atmosphere and are observed by photographic and/or radio astronomical techniques. This data is now evaluated primarily by extrapolation from experiments on another size range and does not permit much differentiation between the iron-nickel and the stone types of meteorites.

Penetration on impact of dust particles in this velocity range is estimated from the extrapolation from larger sizes and lower velocities. This theory predicts that a stony projectile of 0.010-in. diameter and traveling at 70,000 ft/sec would penetrate a dural sheet with a thickness of 3 particle diameters.

Recent experiments have employed shaped charges to obtain velocities as high as 16,400 ft/sec. Armour Research Foundation has obtained a velocity of 4000 ft/sec from an available shock tube and is studying the feasibility of obtaining 60,000 ft/sec. From the best published data, there is almost no hazard from dust particles on space flights of a few days. For large space ships on extended flights and for permanent satellites, the danger is real and requires more study.

F. Todd, USA

4028. Piggott, M. R., The relation between wear and distance run, for steel and coated steel surfaces, *Proc. phys. Soc. Lond. (B)* **69,** 440, 857-858 (Letters to the Editor), Aug. 1956.

4029. Zakharova, T. P., The resistance of metals to repeated overstressing (in Russian), "Strength in unsteady conditions of variable stress," Moscow, Akad. Nauk SSSR, 125-150, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4878.

A survey is given of methods of determining the fatigue resistance with single change in the overload direction; methods of determining the overload resistance from the lowering of the endurance limit, relative life and the fatigue curves of damaged samples are discussed.

It is pointed out that the method of obtaining the curve of susceptibility to damage permits determination of the stress values and number of load cycles causing lowering of the endurances limit owing to overloading.

V. S. Ivanova, USSR

Courtesy Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

4030. Lieblein, J., and Zelen, M., Statistical investigation of the fatigue life of deep-groove ball bearings, *J. Res. nat. Bur. Stands.* **57,** 5, 273-316, Nov. 1956.

Fatigue is an important factor in determining the service life of ball bearings. Bearing manufacturers are therefore constantly engaged in fatigue-testing operations in order to obtain information relating fatigue life to load and other factors. Several of the larger manufacturers have recently pooled their test data in a cooperative effort to set up uniform and standardized ball-bearing application formulas, which would benefit the many users of anti-friction bearings. These data were compiled by the American Standards Association, which subsequently requested that the National Bureau of Standards perform the necessary analyses. This paper summarizes the principal results of the analyses undertaken by the Bureau, and describes the statistical procedures used in the investigation.

From authors' summary

4031. Findley, W. N., Fatigue of metals under combinations of stresses, ASME Ann Meet., New York, N. Y., Nov. 1956. Pap. 56-A-74, 11 pp.

Analysis of available information suggests that the phenomenon of fatigue of materials results primarily from alternating shearing stress producing cracks along shear planes, and that the resistance to fatigue cracking is influenced by other factors. Some of these factors are changes in structure of the material resulting from plastic and elastic stressing as well as heat-treatment; the mode of crack propagation; and the complementary normal stress on planes of shear stress. Several theories of failure under combined stress are examined and modified to account for observed facts. A general design expression is proposed. The influence of mean stress (including extreme compression), yielding, complementary normal stress, and anisotropy are considered.

From author's summary

4032. Elsesser, T. M., Influence of repeated bending loads on biaxial residual stresses in shot-peened plates, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-109, 6 pp.

The futility of shot-peening certain members to increase their fatigue strength may be explained by the reduction of the initial residual stresses with increased numbers of repeated loads. The purpose of this investigation was to determine the changes in the biaxial residual stresses, induced by shot-peening, in steel plates subjected to cyclic bending loads. The plates were sectioned by etching, and curvature measurements were made to evaluate the

residual-stress distributions in the region of the peened surface. The residual stresses were found to "fade" or decrease to at least 50% of their initial value in 10,200 load cycles in the medium-hard (SAE 4340) steel investigated.

From author's summary

4033. Finney, J. M., and Johnstone, W. W., The effect of grain size on the flexural fatigue strength of L40 aluminium alloy, *Aero. Res. Lab. Melbourne, Austral. Note* SM. 231, 7 pp. + 11 figs., July 1956.

Flexural fatigue tests were made on specimens, both unnotched and notched with a drilled hole, cut from L40 aluminum-alloy bulb-angle extrusions containing fine, intermediate, and coarse grains.

The tests indicated that the fatigue strength at 10^6 cycles of the coarse-grained specimens was approximately 10% lower than the specimens containing both fine and intermediate-sized grains.

Many results had to be discarded due to nonuniformity and uncertainty of grain size, and therefore it is recommended that further tests should be made on specimens in which the grain sizes are closely controlled. From authors' summary

4034. Dearden, J., and Swindale, J. D., Effect of alternate corrosion and abrasion on some ferrous metals, *J. Iron Steel Inst. Lond.* **185,** 2, 227-234, Feb. 1957.

The resistance of 11 ferrous metals to atmospheric corrosion, to abrasion, and to certain combinations of both has been compared. Resistance to corrosion was reduced by abrading the rust, and increasing frequency of abrasion increased the corrosion rate, except for grey cast iron which behaved differently from the other materials. The slow-rusting qualities of Cor-Ten steel were not developed under frequent abrasion.

Resistance to abrasion alone was found to be related to a defined equivalent carbon content of the steels tested rather than to their hardness. There was a marked increase in the loss per abrasion of all materials when corrosion alternated with abrasion.

Three white cast irons showed exceptional resistance to corrosion, even when combined with abrasion, and to abrasion alone. Grey cast iron corroded similarly to the unalloyed steels, but with increasing frequency of abrasion its position rose in the order of merit; its resistance to abrasion alone was good.

A selected bibliography on British corrosion tests on iron and steel panels and products, and in various environments, has been included for reference. From authors' summary

Book—4035. Romanoff, M., Underground corrosion, *Nat. Bur. Stands. Circ.* 579, 227 pp., Apr. 1957, $3.

Material Test Techniques

(See also Revs. 3889, 3946, 3973)

4036. Kornhauser, M., Potentialities of the impact machine for producing high accelerations, *Proc. Soc. exp. Stress Anal.* **14,** 2, 21-32, 1957.

A relatively simple low-energy high-acceleration gravity device for applying short-duration shock loads to materials and structures is described. Detailed consideration of material properties, design, and desired performance of machine leads to test specimen on spherical-nose carriage striking semi-infinite anvil. Performance of actual 2-in.-diameter impact machine gives good agreement with theory. Accelerations of up to 22,700 g for 45 microseconds were measured for drop height of about 2 ft. Paper includes discussion of utility of device for testing structures. Suggestions are given for increasing maximum acceleration. Reviewer believes discussion of sizes and shapes of possible specimens would have been of value to potential users. D. K. Felbeck, USA

4037. Evison, F. F., The seismic determination of Young's modulus and Poisson's ratio for rocks in situ, *Géotechnique, Lond.* **6,** 3, 118-123, Sept. 1956.

The velocities of shear and compressional seismic waves in a rock may be used together to calculate the value of Poisson's ratio in situ, and, if the density is known, the value of Young's modulus may be calculated as well. Experiments have been carried out in which these two types of wave were generated first by means of an electrically driven vibrator in the volcanic rock ignimbrite, and secondly in the concrete of a dam. From the velocities measured in each case the following elastic constants were calculated: for ignimbrite, $\mu = 0.41$, E = 460,000 psi; for concrete, $\mu = 0.21$, E = 3,600,000 psi. The value of E for ignimbrite was much smaller than would have been deduced from the compressional velocity alone, with the usual assumption as to the value of μ, and much larger than that given by the standard static compression test. The value for concrete was nearly the same by all three methods.

From author's summary

4038. Vidal, G., Girard, F., and Lanusse, P., A device for testing metals under high frequency sinusoidal alternating stresses (in French), *Genie civ.* p. 157, Apr. 1956.

4039. Bizic, S., Measurement of concrete consistency with the apparatus "Vebe" (in Serbian), *Naše Gradevinarstvo* **2,** 2, 210-212, Oct. 1957.

Author discusses disadvantages of slump tests, especially in cases of low water-cement ratios, which can be avoided by using consistometer VEBE based on the energy consumed in the process of the modification of the primary mass of concrete into the final form. Sensitivity and accuracy of the apparatus is demonstrated by numerical examples. References: C. de la Pena, O. Beijer G. Barcello-J. M. Ricouard, M. Roš. J. J. Polivka, USA

Mechanical Properties of Specific Materials

(See also Revs. 3889, 3939, 3992, 4004, 4009, 4019, 4024, 4031, 4037, 4038, 4169, 4179, 4226)

Book—4040. Boerner, F., Tables of statistics. Regulations for design of buildings in timber, stone, steel and reinforced concrete with formulas and tabulated values for different loadings [Statische tabellen. Berechnungavorschriften mit Lastannahmen, Formel- und Tabellenwerte für sauten aus Holz, Stein, Stahl, und Stahlbeton], 14th ed. by G. Jung; Berlin, W. Ernst & Sohn, 1957, xii + 675 pp., DM 52.

14th edition of this excellent handbook is completely revised with many valuable additions, especially in chapters on strength of materials, statics, reinforced concrete, steel structures, foundations and bridges, with specifications and tables essential for current engineering practice. As the title indicates, the handbook refers basically to structural design, without detailed presentation and discussion of various construction methods and supervision. References are made only to German standard regulations and specifications. J. J. Polivka, USA

4041. Minami, Y., and Fukuda, Y., Deformation of wood due to the change of humidity in atmosphere, *Bull. Fac. Engng., Yokohama nat. Univ.* **6,** 11-20, Mar. 1957.

The relation between rate of change of humidity and that of wood deformation is studied mathematically and experimentally with specimens which are representative of four different Japanese wood species and which were stressed slightly by small compressive or flexural loads.

Summarizing in the most general way, the rates of elongation and contraction in the three principal directions due to change in humidity amount to 2×10^{-4}, 4×10^{-3}, and 8×10^{-3} pct/hr per pct/hr, respectively. E. G. Stern, USA

4042. Timber-concrete composite decks, Service Bureau, Amer. Wood Preservers' Assn., Chicago, 12 pp., 1957.

Complete data are presented for designing creosote-pressure-treated timber-concrete composite decks for highway bridges and other heavily loaded structures.

Typical examples are given of such decks. To form the laminated slab, 2-in. planks on edge are spiked together. By alternating two heights of planks or raising alternate planks 2 in., longitudinal grooves are formed in the slab surface. Shear developers, that is, small trapezoidal steel plates, are partially driven into these grooves to serve as means of connection between laminated deck and concrete surface mat.

E. G. Stern, USA

4043. Noren, B., Bending strength of timber on the flat (in Swedish), *Sven. Träforsklnst. Medd.* no. 783, 17 pp., 1956.

4044. Stone, W. K., Schiefer, H. F., and Fox, G., Stress-strain relationships in yarns subjected to rapid impact loading. Part I. Equipment, testing procedure, and typical results, *J. Res. nat. Bur. Stands.* **54,** 5, 269–276, May 1955.

Authors describe equipment for elongating yarns at velocities between 10 and 100 mps corresponding to rates of straining of 1000 to 5000 per minute. Load elongation curves can be obtained from high-speed cinematographic records of the experiments, and the paper describes a typical test on a nylon yarn.

H. Kolsky, USA

4045. McCrackin, F. L., Schiefer, H. F., Smith, J. C., and Stone, W. K., Stress-strain relationships in yarns subjected to rapid impact loading. Part 2. Breaking velocities, strain energies, and theory neglecting wave propagation, *J. Res. nat. Bur. Stands.* **54,** 5, 277–280, May 1955.

The "limiting breaking velocity" for cotton nylon and undrawn nylon yarns has been measured and applications to safety lines are discussed, as is also the strain energy associated with the stretching process.

H. Kolsky, USA

4046. Smith, J. C., McCrackin, F. L., and Schiefer, H. F., Stress-strain relationships in yarns subjected to rapid impact loading. Part 3. Effect of wave propagation, *J. Res. nat. Bur. Stands.* **55,** 1, 19–28, July 1955.

Authors consider the effect of reflection of waves in filament in terms of perfect elastic behavior, and derive limits for which the simpler treatment used in earlier papers is applicable.

H. Kolsky, USA

4047. Smith, J. C., McCrackin, F. L., Schiefer, H. F., Stone, W. K., and Towne, Kathryn M., Stress-strain relationships in yarns subjected to rapid impact loading. Part 4. Transverse impact tests, *J. Res. nat. Bur. Stands.* **57,** 2, 83–89, Aug. 1956.

Rates of loading of the order of 3000 per minute have been achieved by the use of transverse impact of yarns, and stress-strain curves have been obtained for high tenacity nylon, Fortisan, and Fiberglas from cinematographic records of the motion of the yarn. It is found that, at high rates of strain, these materials have higher initial moduli and remain linear up to higher values of stress than in slower conventional tests.

H. Kolsky, USA

4048. High temperature properties of materials, Proceedings for a short course conducted by The Penn. State Univ., June 21–25, 1954.

Plasticity, Forming and Cutting

(See also Rev. 4142)

Book—4049. Armstrong, W. H., Machine tools for metal cutting, New York, McGraw-Hill Book Co., Inc., 1957, ix + 347 pp. $6.

This is a textbook designed to serve for a one-semester introductory course in machine tools. As such it covers the elements quite well. The basic metal-cutting process is explained, although the diagram of chip formation perpetuates the myth of crack propagation ahead of the tool point. There is a chapter on measurements and one on each of the important machine tool classifications. Automation is touched upon, and the modern processes of electric discharge and ultrasonic machining are also described. For teachers there is a very valuable index of available visual aides, especially films, for classroom use.

E. G. Loewen, USA

Book—4050. Hall, H. D., and Linsley, H. E., Machine tools; what they are and how they work, New York, The Industrial Press, 1957, x + 436 pp. $5.50.

An introduction to the fundamentals of mass production—the tools, machines, gages, and methods that make up our modern metalworking industries and automated production lines.

From foreword

4051. Lustadt, W. S., Further proofs of elementary processes of the workability of materials, *RADEX-Rundschau* no. 8, 398–409, 1956.

Further proofs of elementary processes of the workability of materials and influence on elongation diagrams by ultrasonic waves artificially applied are given; evidence of local heating up on lengthening of high polymer plastics is presented. A separation test is described to determine adhesive strength of adhering compounds as a model to determine processes concerning the workability. Author groups tensile stress-elongation diagrams of different series of materials and attempts to interpret the different shapes of this diagram from viewpoint of statistics.

From author's summary

4052. Johnson, W., Research into some metal-forming and shaping operations, *J. Inst. Metals* **84,** 165–179, 1955–56.

An account is given of the results of both experimental and theoretical investigations carried out at Sheffield University into the drawing and redrawing of cylindrical shells with hemispherical and flat-headed punches, with particular reference to the effects of lubrication, drawing speed, and flange wrinkling; ironing; tube-sinking; the detection and measurement of residual stresses in cold-drawn tubes; impact extrusion under a drop hammer; and coining. Finally, a brief reference is made to problems still outstanding in these fields.

From author's summary

4053. Karpinskii, O. G., and Levitskii, B. M., Residual strains in metals following grinding (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **106,** 1, 55–57, Jan. 1956.

4054. Decroly, C., and Genin, G., Some physico-chemical aspects of oxygen cutting, I, II, III (in French), *Rev. Soudure* **11,** 4, 214–225, 1955; **12,** 1, 50–70, 1956; **12,** 2, 130–138, 1956.

4055. Harrison, P. W., An investigation into the accuracy of the industrial measurement of sizes up to 80 inches, *Proc. Instn. mech. Engrs.* **169,** 47, 977–992, 1955.

Hydraulics; Cavitation; Transport

(See Revs. 4058, 4060, 4099, 4225)

Incompressible Flow: Laminar; Viscous

(See also Revs. 4077, 4104, 4107, 4113, 4120, 4132, 4137, 4139, 4146, 4154, 4174, 4192, 4222, 4223, 4242)

4056. O'Sullivan, J. K., Flow in pipes with drilled holes, *Engineering* **183,** 4760, 684–685, May 1957.

Author reports on experiments on frictional losses in pipes with hole-type rather than usual protrusion-type artificial roughness. Pipes of 0.9- and 1.6-cm diam were studied in the Blasius range. At high Reynolds numbers, the friction coefficient approached a constant multiple of smooth pipe factor, a result previously noted for "surface-waviness"-type roughness. The shallower of the two hole depths studied was found to produce the higher friction, and the increase in friction over the smooth-pipe value was found linear with number of rows of holes or size thereof (as long as holes are not too close).

Results are very similar to those of Ambrose [*Trans. Amer. Soc. civ. Engrs.* **120,** 403–404, 1955] except at lower Reynolds numbers. Reviewer questions propriety of using original pipe diameter (before drilling of holes in sides) as the diameter in analyzing test results. J. M. Roberts, USA

4057. Yih, C.-S., and Sangster, W. M., Stability of laminar flow in curved channels, *Phil. Mag.* (8) **2,** 15, 305–310, Mar. 1957.

Authors investigate laminar flows between two long coaxial cylinders. The width of the channel between the two cylindrical surfaces is small in comparison with the radii of the cylinders.

It is assumed that the primary flow in the narrow space formed by the cylinders is stationary. A solution of the Navier-Stokes' equations for such flows is known (Goldstein).

The neutral stability of the primary flow is calculated by the method of the time-dependent perturbation with small velocity components. The results of the calculation are shown on graphs. The flow becomes unstable as the "stability parameter" increases, which with a constant Reynolds number and a constant channel width is equivalent to an increase in the curvature of the channel. Thus centrifugal forces acting on the liquid determine decisively the instability of the primary flow, and the formation of secondary flows—which in curved channels is unavoidable—cannot be regarded only as a result of the development of boundary layers.

M. Strscheletzky, Germany

4058. Khamrui, S. R., On the slow steady two-dimensional flow of a viscous liquid in a channel bounded by two non-concentric circular arcs, *Bull. Calcutta math. Soc.* **48,** 4, 155–158, Dec. 1956.

Using the linearized equations for slow motion, author obtains a simple analytical solution of the problem. No numerical results are given. D. W. Dunn, Canada

4059. Edmunds, D. E., The moving aerofoil in the neighbourhood of a plane boundary, *Quart. J. Mech. appl. Math.* **9,** 4, 400–424, Dec. 1956.

By extending the method of Green [*Quart. J. Math.* (Oxford), **18,** p. 167, 1948], developed for a stationary airfoil in a uniform stream near a plane wall, author deals with a two-dimensional airfoil moving in an inviscid incompressible fluid bounded by a plane wall. Although the results obtained, which, as in Green's case, are given in series form, apply to a fairly general type of airfoil, yet special attention is paid to those of the flat plate, symmetrical, and circular arc types in order to assess the effects of thickness and camber. Some of the results are new and of practical interest. S. Tomotika, Japan

4060. Khamrui, S. R., On the slow steady rotation of a sphere in a viscous liquid, *Bull. Calcutta math. Soc.* **48,** 4, 159–161, Dec. 1956.

A second approximation to the solution of this problem is obtained by evaluating the previously neglected acceleration terms in the equations of motion by means of the first approximation. The second-order solution has a simple analytical form, and shows that the motion consists of an inflow at the poles of the sphere and an outflow at the equator superposed on a motion of rotation.

D. W. Dunn, Canada

4061. Proudman, I., The almost-rigid rotation of viscous fluid between concentric spheres, *J. fluid Mech.* **1,** 5, 505–516, Nov. 1956.

Two concentric spheres rotate about the same axis with almost the same angular velocity, so that the viscous stresses over the surfaces of the spheres induce a flow which may be represented by a small perturbation superimposed upon a rigid body rotation of the fluid as a whole. The governing equations are therefore linearized in the magnitude of the perturbation, and it appears that the validity of this linearization is independent of the Reynolds number of the primary rotation. Attention is then restricted to the case in which the Reynolds number is large, the principal object of the note being to exemplify some of the properties of rotating systems at large Reynolds number in terms of a particularly simple mathematical model.

It is found that the cylindrical surface that touches the inner sphere (the axis being the axis of rotation) is a singular surface in which velocity gradients are very large. Everywhere outside this cylinder, the fluid rotates as a rigid body with the same angular velocity as the outer sphere. Inside the cylinder, the velocity in the central (inviscid) core of the motion is shown to be determined by the velocity distribution in the boundary layers of the spheres, and explicit solutions are obtained for all these velocity distributions. The mechanics of the cylindrical shear layer itself is also discussed, though no solution is obtained in this case.

From author's summary by J. T. Stuart, England

4062. Woolard, H. W., A theoretical analysis of the viscous flow in a narrowly spaced radial diffuser, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-18, 7 pp.

On the assumption of a finite velocity at a given initial radius a solution is obtained by use of the integral momentum equation taking a quintic form for the laminar velocity distribution. The boundary conditions are correct for the inlet region but approximate only for the fully developed region. The solution applies to the case where the distance between the walls varies with the radius. The fully developed radial flow between parallel walls differs from Poiseuille flow since the pressure falls with radius and leads to separation.

The theoretical results compare favorably with experiment, including the separation position. G. M. Lilley, England

4063. Cummins, W. E., The force and moment on a body in a time-varying potential flow, *J. Ship Res.* **1,** 1, 7–18, 54, Apr. 1957.

The forces and moment acting on a body placed in an arbitrary, steady, potential flow were found by Lagally for the case in which the body can be represented by a system of singularities interior to the surface of the body. The present paper treats the case in which the body is subject to an arbitrary nonsteady motion (including rotation) in a stream which is changing with time. The force and moment are found to be the "Lagally force and moment" which would exist if the instantaneous flow were steady, plus additional components. For the force, these additional components are given as simple functions of the strength of the singularities

used in establishing the boundary condition and of the velocity of the body. However, to obtain the moment, an integration over the surface of the body is required.

From author's summary by H. M. Voss, USA

4064. Gault, D. E., An investigation at low speed of the flow over a simulated flat plate at small angles of attack using pitot-static and hot-wire probes, *NACA TN* 3876, 58 pp., Mar. 1957.

It was found that the large regions of reverse flow (bubbles) cannot be considered regions of "dead air." The reverse flow appears to be part of a more general vortex-type flow. No separated laminar flow was detected at the forward edge of the bubbles.

From the author's summary by A. Petroff, USA

4065. Roy, M., Apex vortices and conical vortex sheets of a delta wing (in French), *Rech. aéro.* no. 56, 3–12, 1957.

Theoretical treatment of vortical flow is given, based on experimental tests in a water tunnel. The potential flow solution valid for flow of a perfect fluid over a delta wing at very small incidence is developed first, and the characteristics of the stream lines of the flow are established.

In experiments at O.N.E.R.A. in 1950–1952, vortex zones were observed to start from the apex of a delta wing at moderate incidences, being formed (as the author stated in 1952) as vortex sheets detaching themselves more or less orthogonally from the upper surface at the leading edge. This is in agreement with the results of Brown and Michael [*J. aero. Sci.* Oct. 1954].

Author derives the equation of this conical vortex sheet using a pseudo-two-dimensional potential theory, with an appropriate source-sink distribution. Some air tends to flow round the leading edge and gets drawn into the center of the vortex spiral, creating a vortex sink. Viscous effects become important (1) at the center of the vortex spiral and (2) at large distances from the apex where the flow is no longer conical. A. W. Babister, Scotland

4066. Taneda, S., Experimental studies of the lift on two equal circular cylinders placed side by side in a uniform stream at low Reynolds numbers, *Rep. Res. Inst. appl. Mech. Kyushu Univ.* **5,** 18, 31–36, 1957.

Experiments confirm results predicted by Fujikawa [*J. phys. Soc. Japan* **11,** 1956] that (1) each of two parallel circular cylinders is repulsed, (2) lift coefficient decreases as Reynolds number increases in range from 0.01 to 1.6, (3) lift coefficient increases, then decreases as ratio of distance between cylinders to cylinder diameter increases. Experiments were done in moving tank containing water-glycerine solution. Lamp, scale, and mirror method was used to measure deflection. Calculation of lift coefficient depends on equations not derived in paper.

D. G. Huber, Canada

4067. Keller, J. B., and Weitz, M. L., Upward "falling" jets and surface tension, *J. fluid Mech.* **2,** 2, 201–203, Mar. 1957.

Authors study the effect of surface tension on the jet according to the hydraulic theory of jets. Without surface tension, according to the simple hydraulic theory of jet, each particle of a jet moves independently along a parabolic trajectory. With surface tension, the jet trajectory changes. For very small initial velocity of jet and large surface tension, according to this theory, the jet rises instead of falling, even though it is initially projected horizontally. Authors state that, in very crude experiments, they have been unable to observe this behavior. They believe this is because the rising flow is unstable at the necessarily low speed.

S. I. Pai, USA

4068. Glauert, M. B., The wall jet, *J. fluid Mech.* **1,** 6, 625–643, Dec. 1956.

When a jet of air strikes a surface at right angles and spreads out radially over it, it forms what will be termed a wall jet. This paper considers the theory of such wall jets, radial or plane, laminar or turbulent. Solutions of the boundary-layer equations are sought, according to which the form of the velocity distribution across the jet does not vary along its length. For laminar flow, such a similarity solution is obtained explicitly. For turbulent flow, an eddy viscosity is introduced, and it is eventually seen that complete similarity is not attainable, but that confident predictions can nevertheless be made about the nature of the velocity distribution and the rate of growth of the wall jet.

From author's summary by S. I. Pai, USA

4069. Gray, F. A., and Robertson, A. D., The deflection of hot jets due to buoyancy, *J. Inst. Fuel* **29,** 189, 424–427, Oct. 1956.

Upward deflections of horizontally projected jets of heated air from square-edged orifices 0.5, 1, and 1.5-in. in diameter, initial temperature elevations 50, 110, and 200 C, were measured and correlated to obtain empirical equation

$$L = 0.1234\,[x^3/U_0^2 d_0]\,[(T_0 - T_a)/T_a] \qquad [1]$$

Deflection L, travel x, and orifice diameter d_0 are in inches, U_0 in ft/sec, and T in degrees absolute. Studies of flow in isothermal models of furnaces neglect buoyancy, and foregoing equation is presented as a first approximation of error so introduced. Paper will be of interest to engineers concerned with flow in furnaces, soaking pits, etc., and to air-conditioning engineers and others interested in the horizontal projection of heated air.

Reviewer's comments: Using consistent units, Eq. [1] may be rewritten

$$L/d_0 = 0.046\,[(T_0 - T_a)/T_a]\,[gd_0/U_0^2]\,(x/d_0)^3$$

Koestel, at Case, obtains [*Trans. ASHAE* **61,** p. 213, 1955]

$$L/d_0 = 0.065\,[(T_0 - T_a)/T_a]\,[gd_0/U_0^2]\,(x/d_0)^3$$

Koestel's equation was developed for a trajectory with slope negligible relative to unity. Similarly, Eq. [1] is based on test values of (L/x) below 0.06. More data over a wider range of conditions are needed. L. Helander, USA

4070. Pykhteev, G. N., Problem of jet flow past a curvilinear arc in a finite and infinite stream of incompressible fluid (in Russian), *Prikl. Mat. Mekh.* **19,** 4, 421–432, July/Aug. 1955.

Author's summary states: "In the present paper is solved the *inverse* problem of the jet motion past a body in a limited and in infinite stream. That means: given velocity distribution, to determine shape of body profile and of jet surface. Analogous problems but without flow separation were considered by G. G. Tumashev [*Uch. Zap. K.G.U.* 1949 and 1952].

Contents and reviewer's observations: §1.–1.2 *Plotting and solving the problem.* Velocity distribution $V = v_0/(s/s_0)$ (1.1), s arch of body profile (author also uses $f(s/s_0) = f(t)$). Author gives main formula $\chi(\zeta) = 1/\pi\sqrt{\zeta^2 - a^2} \int_{-1}^{+1} \ln f \cdot dt/\sqrt{a^2 - t^2}\cdot(t - \zeta)$ (1.5) saying having deduced it from mixed boundary problem. Here ζ and t are complex and real arguments in an auxiliary ζ-plane and $\chi = \ln V/v_0 - i\vartheta$ (1.3), logarithmic hodograph. Then he determines profile shape and jet shape using a conformal mapping $Z(\zeta)$ (1.7) and says $Z(\zeta)$ results sometimes many valued and that the criterion for being univalent is yet unknown.

Reviewer has checked correctness of (1.5). For readers of the original paper, reviewer suggests caution must be taken with function f and the *two* arguments t. Letter f means always the same mathematical quantity but considered as function of different argu-

ments. Author gives a subtle indication of this by writing $f(t)$ in all cases, where $t = s/s_0$ is the relative arch length, as in (1.4), (1.8), (1.9), and by *not putting the argument* after f every time when the *other* t is present in same formula, as in (1.5), (1.6), (1.10). This other t is the above-mentioned real argument in the ζ-plane, i.e., coordinate of double sources for Dirichlet problem, and f means now the density of these double sources. Finally, the f in (1.5) must become function of this other t instead of the first, but this is done by means of a functional transformation which the author does not state clearly in the general explanation (§1.-1) but which he uses later in particular cases (§1.-4, last of 1.29). There is a third t, in (1.24)-(1.27); it is a parameter.

(§1.-3). *Technique of calculation of the integral in (1.5) and (1.10).* Author uses infinite series and auxiliary arguments.

(§1.-4). *Particular velocity distribution.* $V = v_0 \operatorname{tg}(\pi s/4s_0)$ (1.28) leads to an exact solution; reference [6] for tabulated integrals.

(§2.-1,2,3). *Jet motion past body in infinite stream.* Author gives general solution, plots Kirchhoff's condition (no intersection of the two jets), and gives an exact solution for $V = v_\infty (s/s_0)^\alpha$.

(§3.-1...5). *Solutions for some curved profiles.* Author gives exact solutions for some classes of curves in limited and infinite stream, checking them by comparison with known formulas for plane plates; also some approximate solutions.

Reviewer believes author's investigations are useful for many hydrodynamic applications (e.g., discharge coefficients for nozzles, lattices, etc.). The method is general and can be extended to more cases.

Six bibliographical references in Russian are given.

N. Krivoshein, Argentina

4071. Hall, I. M., The displacement effect of a sphere in a two-dimensional shear flow, *J. fluid Mech.* **1,** 2, 142-162, July 1956.

The objective is to provide a theoretical assessment of the effective displacement of a pitot tube in a shear flow due to the displacement from the tube axis of the stagnation streamline. This problem was investigated experimentally in 1936 by Young and Maas, who found the displacement to be about 0.18 of the tube diameter for a wide range of transverse rates shear of the undisturbed flow. In this paper a solution is found in the plane of symmetry for the flow past a sphere. The solution involves a plausible assumption about the rate of stretching of vortex tubes perpendicular to the plane of symmetry which is based on the international flow solution, and the shear flow is regarded as a small perturbation of a uniform flow, the solution being obtained in the form of series in terms of a nondimensional parameter involving the transverse rate of shear. The results show the displacement effect to be of the same order as that measured by Young and Maas, but it is somewhat more sensitive to the magnitude of the transverse rate of shear than is suggested by the experimental results. A theoretical investigation of the corresponding problem in two dimensions for the flow past a circular cylinder and two parallel semi-infinite plates shows the displacement effect there to be much smaller than in three-dimensional flow. This difference is ascribed to the stretching of the vortex tubes around the three-dimensional object and the consequent increase in vorticity in the region of the body nose.

A. D. Young, England

4072. Sanyal, L., The equations of motion of an incompressible viscous fluid in the parallel system of coordinates, *Indian J. Phys.* **31,** 1, 6-10, Jan. 1957.

For a rigorous deduction of the equations of three-dimensional boundary layer on a given surface, the Stokes-Navier equations of motion of an incompressible viscous fluid under no body forces have been transformed in the parallel system of coordinates.

From author's summary by T. R. Gullstrand, Sweden

4073. Grieb, A. A., A particular solution of the equations of plane, cylindrical and spherical waves (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **102,** 2, 225-227, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4258.

For the equations of a one-dimensional unsteady flow of an ideal gas

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial r} + \frac{2}{k-1}a\frac{\partial a}{\partial r} = \frac{a^2}{k-1}\frac{\partial \ln \vartheta}{\partial r}$$

$$a\frac{\partial u}{\partial r} + \frac{2}{k-1}\frac{\partial a}{\partial t} + \frac{2}{k-1}u\frac{\partial a}{\partial r} + (n-1)\frac{au}{r} = 0 \qquad [1]$$

$$\frac{\partial \vartheta}{\partial t} + u\frac{\partial \vartheta}{\partial r} = 0 \qquad \left(\vartheta = \frac{p}{\rho^k}\right)$$

(a speed of sound; k adiabatic exponent), author finds particular solutions of the form

$$u = T(t)V(r); \qquad a = T(t)C(n); \qquad \vartheta = T_1(t)S(r);$$

$$T(t) = \frac{1}{1+mt}; \qquad T_1(t) = \frac{1}{(1+mt)^q},$$

V, C, and S are determined by the equations

$$\frac{d}{dr}\left(\frac{V^2}{2} + \frac{C^2}{k-1}\right) = mV + \frac{C^2}{k-1}\frac{mq}{v};$$

$$\frac{d}{dr}\ln\left[VC^{\frac{2}{k-1}}r^{(n-1)}\right] = \frac{2}{k-1}\frac{m}{V}; \qquad [2]$$

$$V\frac{d\ln S}{dr} = mq.$$

The following cases are examined:
(1) $m = 0$, $n = 2$, and $n = 3$; (2) $q = 0$, $n = 2$ and $n = 3$; (3) $q = 0$, $n = 1$; (4) $q = 0$.

(Abstractor's note): For unsteady ($m \neq 0$), anisentropic ($q \neq 0$) motion, the solutions of Eqs. [2] have the form

$$V = \frac{2m}{2n + n(k-1)}r, \quad C = \frac{m(k-1)}{2 + n(k-1)}\sqrt{\frac{2n}{2-mq}}\,r;$$

$$S = c_1 r^{\frac{1}{2}q[2+n(k-1)]} \qquad (c_1 = \text{arbitrary constant}).$$

Author has only established a partial case of this solution, for $q = 0$ (isentropic motion). Solutions in which $V = \alpha r$ (α = constant) have been investigated in detail by L. I. Sedov [*Ref. Zh. Mekh.* 1953, Rev. 568; "Similarity and dimensional methods in mechanics"; 3rd ed, Moscow, Gostekhizdat, 1954, chap. IV].

N. L. Krasheninnikova, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4074. Golubeva, O. V., Some problems of the filtration of liquids in curved strata (in Russian), *Uchen. Zap. Mosk. obl. ped. in-ta* **33,** 15-23, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3752.

Analysis of problems concerning the discharge volumes of boreholes draining some particular forms of homogeneous curved strata. The investigations were based on a paper published earlier by the same author [*Prikl. Mat. Mekh.* **14,** 3, 287-294, 1950]. The curved strata of constant thickness are considered in the form of either a cone, or a dome bounded by the surfaces of a paraboloid of rotation, or a sphere. These strata are drained either by single boreholes at the apexes of the corresponding surface or by batteries of boreholes.

Investigation of the draining of a curved stratum by a single bore or a system of holes leads to the problem of constructing the flow potential for a correspondingly curved surface. Some of these problems have already been considered by P. Ya. Polubarinova-Kochina [*Prikl. Mat. Mekh.* **14,** 1, 57-64, 1950].

The solution given for the problem of the discharge of a single hole-and-drift encircling the peak of a circularly conical stratum has already been presented by V. P. Pilatovskii [*Ref. Zh. Mekh.* 1955, Rev. 1437]. V. P. Pilatovskii, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4075. Mirzadzhanzade, A. Kh., Abasov, M. T., and Dzhalilov, K. N., Influence of a change in viscosity with temperature on the filtration of an incompressible liquid (in Russian), *Izv. Akad. Nauk AzSSR* **9**, 3–6, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3757.

The steady filtration of a homogeneous incompressible liquid toward a central borehole in a homogeneous, conical stratum is examined for the viscosity-temperature relationship. For a given law of temperature distribution in the stratum, and approximating a broken curve of the viscosity-temperature relationship, authors obtain an expression for the delivery from the bore. Comparison of the calculated results with the calculated delivery for a viscosity corresponding to the mean temperature in the stratum shows that in certain cases consideration of variations in the viscosity is of great importance. G. I. Barenblatt, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Compressible Flow, Gas Dynamics

(See also Revs. 4101, 4121, 4129, 4130, 4144, 4149, 4151, 4155, 4162, 4181, 4185)

Book—4076. Donovan, A. F., and Lawrence, H. R., edited by, Aerodynamic components of aircraft at high speeds (High-speed aerodynamics and jet propulsion, Vol. 7), Princeton, N. J., Princeton University Press, 1957, xiv + 845 pp. $17.50.

Vol. VII of this collective work is the second of a group of three [Vols. VI to VIII] which "intend to present the entire theoretical and experimental picture of external aerodynamics of aircraft configurations." Vol. VI was published in 1954 [AMR **8**, Rev. 1094]. Vol. VII contains "Aerodynamics of wings at high speeds" by R. T. Jones and Doris Cohen, 243 pages; "Aerodynamics of bodies at high speeds" by Clinton E. Brown, 37 pages; "Interaction problems" by C. Ferrari, 271 pages; "Propellers for high-speed flight" by C. B. Smith, 34 pages; "Diffusers and nozzles" by J. C. Evvard, 72 pages; "Nonsteady wing characteristics" by I. E. Garrick, 121 pages; "The experimental aerodynamics of wings at transonic and supersonic speeds" by C. W. Frick, 39 pages.

One should consider this volume and its articles in two ways, on their own merit and as parts of the group. For some years the readers and users of Vol. VI have been looking forward to a Vol. VII that would bring concrete material for design, i.e., the application of the extensive theoretical articles in Vol. VI. Reviewer feels that the new volume presents valuable material, but the relation to Vol. VI is not always visible. More coordination on the editorial level would have been desirable. There are repetitions and overlaps which may be confusing to some users of the collective work. In addition, one wonders why the editors of this volume did not try to keep more control over the different articles. According to the title one expects that supersonic flow considerations predominate and take more space than the treatment of subsonic flow. However, subsonic, one might even say incompressible, considerations take so much space in Ferrari's section that it looks as if inclinations of authors had been stronger than editorial policy. It may be that single monographs on the different topics would have avoided this and other criticism.

Jones's original way of thinking is reflected in his article; basic essentials are given without too many mathematical details. Tables of functions and diagrams help understand the relation between shape and load of wings. Cohen's work here is very visible. Brown's critical article is close to some sections of Vol. VI, but gives additionally the stability derivatives. Ferrari presents the widely scattered material on interaction in great detail. This saves looking up the cited papers; however, the reviewer would have preferred in some parts a more concise presentation (similar to Garrick's article). The subsonic part contains wing-tail, wing-body and propeller-wing interference; the supersonic part, wing-tail and wing-body interference only. Smith has written a guide for the practical engineer who faces the task of designing a propeller operating at supersonic velocities. Evvard's section gives a thorough discussion of the difficulties of diffuser and nozzle design connected with the fact that these airplane parts should be at optimum working condition for a given Mach number, but must not fail under other conditions. Based on a fine knowledge of the numerous papers on nonsteady wing characteristics, Garrick has written a critical article. Methods, results and limitations of the different procedures are clearly stated and equally well the "status as of today" of the complicated three-dimensional problem. Frick's article does not concern techniques of experiments but comparison of theoretical and experimental results. Such comparisons are scattered over Vol. VI and this volume. However, the reader will enjoy Frick's concise presentation.

I. Flugge-Lotz, USA

4077. Milne-Thomson, L. M., A general solution of the equations of hydrodynamics, *J. fluid Mech.* **2**, 1, p. 88, Jan. 1957.

Author shows that the equations of motion are satisfied by certain relations for density, velocity, and stress distribution. A physical interpretation of the results, which would be of much interest to the reader, is not given in the present paper.

I. I. Glass, Canada

4078. Hancock, G. J., Note on the extension of Evvard's method to wings with subsonic leading edges moving at supersonic speeds, *Aero. Quart.* **8**, part 1, 87–102, Feb. 1957.

With Evvard's method, a source distribution procedure, the pressure is obtained as an integral of the downwash over specified regions of the wing surface ahead of the pressure point. This method is (see title) here further developed, although in the past, for particular cases, the problem of subsonic leading edges has been treated by methods of harmonic transformation, operational, doublet line, and conical fields. However, it is pointed out that study of the Evvard method has possibilities of good application since (1) its generality covers planform and camber, and would be useful in aeroelastic problems, and (2) a path is indicated for obtaining oscillatory derivatives.

In the present paper, two solutions are investigated by (1) replacing the upwash integrals by integrals over the wing surface, leading to a numerical solution which can be computed to any desired accuracy, and (2) approximations made for the upwash velocities, resulting in a series of standard integrals. Using method (2), solutions are obtained for the pressure loading on a flat plate triangular wing and a cropped delta wing. Application to other planforms and cambered airfoils is discussed.

J. DeYoung, USA

4079. Kaplan, G., On subsonic flow past a paraboloid of revolution, *NACA TN* 3700, 21 pp., Feb. 1957.

Janzen-Rayleigh method of expansion in powers of free-stream Mach number M is used to calculate velocity potential for steady subsonic flow past a paraboloid of revolution. First two terms are calculated, first being incompressible solution, and second term in M^2. Closed expression is obtained for second term in form of double infinite integral containing Bessel functions under integral sign. This integral is not evaluated numerically. Expressions for fluid velocity are given as correction factors by

which corresponding expressions for incompressible flow are multiplied to allow for effects of compressibility.

From author's summary by D. W. Holder, England

4080. Jones, W. P., The oscillating aerofoil in subsonic flow, *Aero. Res. Counc. Lond. Rep. Mem.* 2921, 16 pp., 1956.

There are discrepancies between the values of the aerodynamic coefficients given by existing methods [Minhinnick, British R.A.E. Report Structures 87, 1950, and AMR **5**, Rev. 1475]. Primary purpose of this paper is to develop a new method of calculating these coefficients for two-dimensional flow for a range of frequency parameters.

Airfoil is replaced by a flat plate and linearized theory is used. The downwash is determined by an integral equation involving the circulation. In an earlier report [Jones, *Aero. Res. Counc. Lond. Rep. Mem.* 2855] this is solved to a first-order approximation in frequency parameter. In present paper the integral equation is replaced by an equivalent set of linear algebraic simultaneous equations, the circulation being represented by a sum of terms occurring in incompressible flow theory.

Tables of aerodynamic coefficients are given for $M = 0.7$ and 0.8, and good agreement is obtained with Minhinnick's values. It was found that solutions of sufficient accuracy could be obtained by using only four terms in the series for the circulation.

A. W. Babister, Scotland

4081. Sinnott, C. S., An experimental investigation of Meksyn's transonic inviscid flow theory, *Aero Res. Counc. Lond. curr. Pap.* 302, 9 pp. + 5 figs., 1956.

Meksyn's method for the approximate solution of the equations of transonic flow theory for flows with free-stream Mach numbers less than unity is reviewed and examined critically from both the theoretical and experimental point of view. Special attention is devoted to the flow past a Kaplan bump. It is concluded that this theory provides a satisfactory, if rather laborious, means of calculating subcritical pressure distributions, but that the calculated supercritical pressure distributions, as well as Meksyn's criterion for the first appearance of a shock wave, are at wide variance with experimental results.

J. R. Spreiter, USA

4082. Freeman, N. C., On the stability of plane shock waves, *J. fluid Mech.* **2**, 4, 397–411, June 1957.

Using an extension of Lighthill's linearized solution for the diffraction of plane shock waves, author investigates the behavior of a plane shock wave perturbed by small finite disturbances (such as symmetrical roof-top obstacles in a shock tube). An expression is obtained for the decay of the perturbation and hence for the stability of the shock. Comparison of theory with experimental results indicates qualitative agreement only, and author concludes that the discrepancy is due to the difficulty of setting up experimental conditions in agreement with those assumed in the theory.

S. F. Borg, USA

4083. Chisnell, R. F., The motion of a shock wave in a channel, with applications to cylindrical and spherical shock waves, *J. fluid Mech.* **2**, 3, 286–298, May 1957.

If shock moves in a channel whose cross section varies sufficiently slowly, relation between shock strength and area change can be found in a closed form. Application to converging cylindrical and spherical shocks where exact solutions are known shows close agreement. Reasons for close agreement are examined.

G. Guderley, USA

4084. Payne, R. B., A numerical method for a converging cylindrical shock, *J. fluid Mech.* **2**, 2, 185–200, Mar. 1957.

A finite-difference method [Lax, P. D., *Comm. pure appl. Math.* **7**, 159–193, 1954; AMR **9**, Rev. 6] is applied to the calculation of a converging cylindrical shock as it moves inward toward the axis of cylindrical symmetry. The artifical diffusion term which is introduced does not represent the correct viscosity or thermal conductivity effects, but produces similar results in the flow except within the shock interior.

A converging cylindrical shock is found to increase in strength (maximum pressure rise), nearly according to the formula of Chisnell. The artificial diffusion causes the pressure to remain finite at the axis; however, a reflected diverging shock is obtained.

A. H. Shapiro, USA

4085. Alpher, R. A., The Saha equation and the adiabatic exponent in shock wave calculations, *J. fluid Mech.* **2**, 2, 123–126, Mar. 1957.

When shock waves have become so strong that the gas is ionized, the usual treatment using the adiabatic exponent γ is no longer adequate. Author presents improved method of treatment with adequate references to the literature to permit reader to learn all necessary details. The magnitude of error made by using the adiabatic exponent rather than the "effective" γ is shown for several cases.

H. W. Emmons, USA

4086. Whitham, G. B., A new approach to problems of shock dynamics, Part I; Two-dimensional problems, *J. fluid Mech.* **2**, 2, 145–171, Mar. 1957.

A shock moving into stationary fluid containing various obstacles has, in general, different slopes and strengths at any given time. The new approach regards such changes as disturbances propagating along the shock front as it moves. The entire theory of one-dimensional wave propagation is available and permits the solution of many interesting problems such as the shock movement over angles and wedges, the stability of plane and cylindrical shocks. A most interesting feature is the prediction of the formation of triple shock intersections—i.e. Mach reflections—in a simple and accurate way.

H. W. Emmons, USA

4087. Kuerti, G., and Faymon, K., One-dimensional shock-motion of a gas with $\gamma = 3$, enclosed between fixed walls, *J. Math. Phys.* **35**, 4, 384–393, Jan. 1957.

This mathematical paper presents the solution of the shock problem in a closed tube for one of the special choices of γ for which the problem can be integrated in terms of elementary functions [Courant & Friedrichs, "Supersonic flow and shock waves," p. 90]. Results are presented in the familiar form of wave diagrams.

R. E. Street, USA

4088. Meyer, R. E., On the measurement of supersonic aerofoil drag by pressure traverse, *Aero. Quart.* **8**, part 2, 123–144, May 1957.

The drag is expressed in terms of distributions of static pressure, stagnation pressure, and stagnation temperature along a traverse line between the nose shocks. Considering the contributions to the drag from the traverses of the wake and of the region outside the wake separately, the relative importance of the various terms in the drag integral are discussed in great detail, and the errors introduced by theoretical approximations and experimental inaccuracies are evaluated, with numerical examples for small intermittent tunnels at medium Mach numbers.

For region between nose and tail shocks, second-order theory is in some cases inadequate and further theoretical work is needed. The main experimental difficulty is found to be the accurate determination of shock location. The wake contribution is found, ignoring changes in total temperature. This error may be partly compensated by the error introduced by ignoring heat transfer at the model. The main experimental difficulty is the accurate determination of the wake width. Further work on the pitot-tube displacement effect is needed.

Paper is a substantial contribution to the theory of the subject, but method is still, in reviewer's opinion, too cumbersome for practical application, except in a limited number of special cases.

N. H. Johannesen, England

4089. Kawamura, R., and Karashima, K., On the wave drag of wing-body combination moving at supersonic speeds, *J. Japan Soc. aero. Engng.* **5**, 39, 1–7, Apr. 1957.

Wave drag results in relatively equal contributions from bodies and wings for modern configurations. Using source distributions, an interference potential function for those components is developed from linearized small-perturbation theory. The potential is made to satisfy appropriate boundary conditions on both the wing and lateral symmetry planes. Interference drag is shown to be generally of the same order as that for wing or body alone, and one illustrative example is included.

J. R. Baron, USA

4090. Nielsen, J. N., Tables of characteristic functions for solving boundary-value problems of the wave equation with application to supersonic interference, *NACA TN* 3873, 245 pp., Feb. 1957.

Tables are presented containing 69,000 values of a set of characteristic functions of two variables which first arose in problems of supersonic wing-body interference. The functions solve boundary-value problems of the second kind for the wave equation in three dimensions with circular cylindrical boundaries or problems of the unsteady heat-conduction equation in two space dimensions with circular boundaries. The functions themselves have the physical significance of cylindrical pressure waves. The tables have extensive use in problems of aerodynamic interference at supersonic speeds.

From author's summary by A. van Heemert, Holland

4091. Edse, R., Design of supersonic expansion nozzles and calculation of isentropic exponent for chemically reacting gases, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-106, 21 pp.

Methods are presented for calculating differential and integral values of the isentropic exponents in gases without and with consideration of chemical reactions. A numerical evaluation of the method is given for dissociating hydrogen. The results of this investigation indicate that the isentropic exponent of a chemically reacting gas mixture differs greatly from the ratio of the specific heats. It is also shown that accurate designs of supersonic expansion nozzles for chemically reacting gases require a detailed thermodynamic analysis of the system.

From author's summary by J. R. Stalder, USA

4092. Gadd, G. E., Holder, D. W., and Regan, J. D., Base pressures in supersonic flow, *Aero. Res. Counc. Lond. curr. Pap.* 271, 10 pp. + 21 figs., 1956.

The problem of accurately predicting the pressure and wake configuration at the base of bodies in supersonic flow is an extremely important one inasmuch as a sizeable portion of the total drag of a given body may be attributable to the low pressure in this region. Although a great deal of theoretical and experimental work has been done in this field, there does not yet exist a satisfactory method for accurate predictions.

This paper represents an excellent effort to experimentally confirm analytically deduced concepts. A large amount of experimental data on body shapes such as wedges, cones, and cone-cylinders has been obtained over a range of Mach numbers up to 4. The data are thoroughly discussed with respect to analytical deductions. On the basis of the evidence accumulated it is concluded that the boundary-layer thickness has only a small effect on the base pressure for axisymmetric bodies and for two-dimensional bodies when the base height-to-chord ratios are of the order 1/10 to 1/20.

Reviewer believes this report is a significant contribution in the field of base pressure and wake flow phenomena.

J. Persh, USA

4093. Lomax, H., and Heaslet, M. A., A special method for finding body distortions that reduce the wave drag of wing and body combinations at supersonic speeds, *NACA Rep.* 1282, 38 pp., 1956.

For a given wing and supersonic Mach number, the problem of shaping an adjoining fuselage so that the combination will have a low wave drag is considered. Only fuselages that can be simulated by singularities (multipoles) distributed along the body axis are studied. However, the optimum variations of such singularities are completely specified in terms of the given wing geometry. An application is made to an elliptic wing having a biconvex section, a thickness-chord ratio equal to 0.05 at the root, and an aspect ratio equal to 3, A comparison of the theoretical results with a wind-tunnel experiment is also presented.

From authors' summary by A. R. Mitchell, Scotland

4094. Ferri, A., and Libby, P. A., A new technique for investigating heat transfer and surface phenomena under hypersonic flow conditions, *J. aero. Sci.* **24**, 6, 464–465, June 1957.

Authors point out that the boundary layer in many hypersonic flows can be simulated by a flow at low Mach number in which one tailors the inviscid flow field. Wind-tunnel walls may be designed to duplicate actual hypersonic pressure distribution so that heat-transfer measurements will be made on a test body. This reviewer cautions readers that heat transfer resulting from molecular dissociation and from radiation is not simulated by this technique; for many problems, however, this technique is valuable.

W. Griffith, USA

4095. Yasuhara, M., On the hypersonic viscous flow past a flat plate with suction or injection, *J. phys. Soc. Japan* **12**, 2, 177–182, Feb. 1957.

Author extends Stewartson's treatment of shock-wave and boundary-layer interaction in hypersonic flow over a flat plate [AMR **9**, Rev. 805] to include suction or injection; in particular, when the suction or injection velocity is proportional to $x - \frac{1}{4}$. The "boundary layer" is solved by the Karman integral procedure. Several numerical examples are given, showing that suction appears to affect only the velocity profile without much change of the shock layer thickness or the pressure distribution along the plate.

S. F. Shen, USA

4096. Walker, P. B., The structural effects of kinetic heating in supersonic flight, *AGARD Publications* AG20/P10, 75–81, June 1955.

4097. Unterberg, W., An analysis of heating problems in supersonic ramjet tailpipes, *Jet Propulsion* **27**, 5, 514–521, May 1957.

For externally mounted supersonic ramjets, cooled principally by exposure to the surrounding free stream, heat-transfer methods are used to predict temperatures attained by single-walled tailpipes during ground and air launch transients and at steady-state conditions in the range of flight Mach numbers up to 4 and altitudes up to 100,000 ft. It is concluded that single-walled metal tailpipes, internally ceramic-coated where necessary, encounter a thermal barrier only in the high Mach number-low altitude region where more complex cooling means are required. A high performance variable-geometry "paper" ramjet was chosen as example, with internal gases at 4000 F throughout, near the maximum obtainable from hydrocarbon-air combustion. Graphs show how the tailpipe metal temperature at thermally critical locations is af-

fected by the major variables of steady-state flight conditions, ground and air launch transients, tailpipe exit geometry, wall thickness and wall material. Turbojet-afterburner tailpipes would experience the same thermal severity. Based on the analysis, engine size effects and thermal design factors for single-walled tailpipes are discussed. Also, a survey of more complex cooling systems is included. The heat-transfer assumptions, methods, and data employed in the analysis are contained in the appendix.

From author's summary

Wave Motion in Fluids

(See also Revs. 3882, 4237, 4243)

4098. Apte, A. S., and Kravtchenko, J., Theoretical and experimental study of flow of heavy liquids with free surfaces (in French), *Publ. sci. tech. Min. Air, France* no. 333, 114 pp., 1957.

This volume has three parts concerning separate, related, topics.

The first part studies the conformal transformation between a channel with a step and a channel with a right-angled bend. For suitable choice of the two available parameters, the image in the latter region of a certain line in the former region is found to satisfy to very close approximation (0.4% in height) the free surface condition for solitary wave with angular (120°) crest.

The second part is a painstaking theoretical treatment of wave spectrum produced by a mechanical wave generator for a tank, involving detailed geometrical study of the linkage, and harmonic analysis of its motion.

The third, and major, part is a theoretical and experimental study of waves occurring in a rectangular basin connected with the sea by a long channel. At cost of a slightly more artificial model, the theoretical treatment by McNown and Kravtchenko [AMR **7**, Rev. 3073 and AMR **9**, Rev. 797] is improved, particularly for resonant waves. Fourier expansion in horizontal rectangular coordinates is used. Agreement with experiment is very good.

A. H. Armstrong, England

4099. Long, R. R., Solitary waves in one- and two-fluid systems, *Tellus* **8**, 4, 460–471, Nov. 1956.

Paper seems to be an important contribution to the solution of this intricate problem. After giving a brief historical review, author develops his own research to obtain better approximations in formulas for wave-translation velocity and in limiting conditions for maximum amplitude at the crest. Chief results are the following.

Part I. The Solitary Water-Wave. Wave-speed formula (6) and (46):

$$F^2 = 1 + \alpha - 1/20\ \alpha^2 - 3/70\ \alpha^3 - 6/175\ \alpha^4 - 2427/77000\ \alpha^5 + 0(\alpha^6),$$

where $\alpha = a/b$ is relative amplitude at the crest, $F^2 = C^2/gb$ is Froude number. Approximations: $1 + \alpha$ by Scott Russel (1844), Boussinesq (1871), Rayleigh (1876); $-1/20\ \alpha^2$, instead of Weinstein's (1926) $-21/20\ \alpha^2$, was corrected by author; $-3/70\ \alpha^3$–$6/175\ \alpha^4$ by author (by direct integration); $-2427/77000\ \alpha^5$ by author (by the momentum theorem). Also McCowan's (1891, 1894) and other approximations (till 1954) are mentioned.

In his mathematical deductions, done in a very elegant manner, author uses a number of quite different procedures. He operates always in relative coordinates (steady motion) and no introductory approximations until the right step for it is reached; many of the results are obtained by wittily established inequalities.

Author guesses prudently that all further terms of (46) would be negative, thus (46) represents the *upper limit* for wave speed. Also he deduces a *lower limit* for it and gives a graph and a table. Also he gives suggestions for maximum amplitude ($\alpha m = 0.813$), comparing it with data by others; a reference to the undular jump (Rouse, 1938) is made.

Part II. The Solitary Wave in a Two-Fluid System. (Top and bottom of channel are fixed boundaries.)

The deduction is made in same elegant manner as in part I. Direct potential and flux-functions are used (in part I are inverse functions). The two-fluid problem seems to be more complicated than the single one, though author reaches only to the second approximation, i.e. $0(\alpha^3)$ and paper gives only a very brief extract of deductions.

Two Froude numbers are introduced: (19) $F_1^2 = p_1 u_1^2/g(p_1 - p_2)b$ and $F_2^2 = p_2 u_2^2/g(p_1 - p_2)b$, where b is the depth of the lower fluid; a criterion for possibility of elevation—and depression—wave is given (never are both forms possible in same conditions).

For both fluids at rest in infinite ($F_1 = F_2 = F$), author gives wave speed formula [23] $F^2 = (1 - R)\,[1 + \alpha(1 - 2R)/(1 - R)] + 0(\alpha^2)$ (where $R = b/H$, H channel height) as first approximation; gives wave profile, too, then gives a second approximation for the general case. Finally, he gives, for $F_1 = F_2 = F$ and $p_1 \approx p_2$, a condition for maximum amplitude [35] $|\alpha|_{\max} \leqslant 4R(1 - R)^2 \cdot |1 - 2R|/(1 - 3R + 3R^2)$ and a graph for $|\alpha|_{\max}$ and for $R \cdot |\alpha|_{\max}$ having two maxima (one for elevation, other for depression wave). For $R = 0.5$ (equal fluid-layers), $|\alpha|_{\max} = 0$, hence permanent solitary wave results are impossible.

Other indications are given, too. Extensive bibliographical references are given.

N. Krivoshein, Argentina

Turbulence, Boundary Layer, etc.

(See also Revs. 4062, 4066, 4068, 4071, 4072, 4094, 4095, 4119, 4152, 4174, 4184, 4190, 4231)

4100. Grant, H. L., and Nisbet, I. C. T., The inhomogeneity of grid turbulence, *J. fluid Mech.* **2**, 3, 263–272, May 1957.

The intensity of turbulent motion in the wake of square mesh grids of bars has been examined experimentally. The measurements show that there are considerable departures from homogeneity over surfaces normal to the mean stream. Large variations of intensity have been observed at a distance of 80 mesh lengths from the grid, where they are diminishing slowly, if at all. This inhomogeneity is believed to be the cause of the discrepancies between various sets of measurements of energy decay in the "initial period." There is also a possibility of error in other measurements made in grid turbulence and analyzed on the assumption of homogeneity. Observations with a grid of 2-in. mesh show that $\overline{v^2}$ is significantly less than $\overline{u^2}$, which is consistent with results from other laboratories.

From authors' summary by E. Leimanis, Canada

4101. Malkus, W. V. R., Outline of a theory of turbulent shear flow, *J. fluid Mech.* **1**, 5, 521–539, Nov. 1956.

In this paper the spatial variations and spectral structure of steady-state turbulent shear flow in channels are investigated without the introduction of empirical parameters. This is made possible by the assumption that the nonlinear momentum transport has only stabilizing effects on the mean field of flow. Two constraints on the possible momentum transport are drawn from this assumption: first, that the mean flow will be statistically stable if an Orr-Sommerfeld-type equation is satisfied by fluctuations of the mean; second, that the smallest scale of motion that can be present in the spectrum of the momentum transport is the scale of the marginally stable fluctuations of the mean. Within these two constraints, and for a given mass transport, an upper limit is sought for the rate of dissipation of potential energy into heat. Solutions of the stability equation depend upon the shape of the mean velocity profile. In turn, the mean velocity profile depends upon the spatial spectrum of the momentum transport. A variational technique is used to determine that momentum transport spectrum which is both marginally stable and produces a maximum

dissipation rate. The resulting spectrum determines the velocity profile and its dependence on the boundary conditions. Past experimental work has disclosed laminar, "transitional," logarithmic, and parabolic regions of the velocity profile. Several experimental laws and their accompanying constants relate the extent of these regions to the boundary conditions. The theoretical profile contains each feature and law that is observed. First approximations to the constants are found, and give, in particular, a value for the logarithmic slope (von Kármán's constant) which is within the experimental error. However, the theoretical boundary constant is smaller than the observed value. Turbulent channel flow seems to achieve the extreme state found here, but a more decisive quantitative comparison of theory and experiment requires improvement in the solutions of the classical laminar stability problem.

From author's summary by E. Leimanis, Canada

4102. Betchov, R., An inequality concerning the production of vorticity in isotropic turbulence, *J. fluid Mech.* **1,** 5, 497–504, Nov. 1956.

An inequality is demonstrated involving the rate of production S of mean-square vorticity in isotropic turbulence and a factor γ which may be said to allow for intermittency or for the non-vanishing of fourth-order cumulants. An extreme state, corresponding to equality of this relationship, occurs if $S = 0.64$ and $\gamma = 2.14$. The experimental values are $S = 0.4$ and $\gamma = 4$. Another kinematical relation shows that the mechanism of vorticity production resembles collision between fluid particles rather than the swirling of contracting jets.

From author's summary by E. Leimanis, Canada

4103. Acharya, Y. V. G., Spectrum of axi-symmetric turbulence in a contracting stream, *Proc. Indian Acad. Sci.* (*A*) **44,** 2, 63–71, 1956.

Previous workers have calculated the effect of an axisymmetric contraction on homogeneous isotropic turbulence, with the linearizing assumption that the contraction is "sudden" and has the effect of straining all parts of the fluid in the same way. In this paper a similar calculation is attempted for turbulence which is initially axisymmetric. Definite results are obtained in the particular case in which the two scalar functions defining the spectrum function are initially functions of the wave-number magnitude alone.

G. K. Batchelor, England

4104. Rossow, V. J., On flow of electrically conducting fluids over a flat plate in the presence of a transverse magnetic field, *NACA TN* 3971, 54 pp., May 1957.

The use of a magnetic field to control the motion of electrically conducting fluids is studied. The boundary-layer solutions are found for flow over a flat plate when the magnetic field is fixed relative to the plate or to the fluid. The equations are integrated numerically for the effect of the transverse magnetic field on the velocity and temperature profiles, and hence, the skin friction and rate of heat transfer. (*From author's summary.*)

The influence of the magnetic field is studied for several special examples to give the reader some physical intuition into the processes occurring. In all the examples but one, constant coefficients describe the fluid where used. It is not completely clear what the effect would be of taking into account the influence of the flow on the fields as well as that of the field on the flow.

W. Griffith, USA

4105. Cohen, N. B., A power-series solution for the unsteady laminar boundary-layer flow in an expansion wave of finite width moving through a gas initially at rest, *NACA TN* 3943, 56 pp., June 1957.

An approximate solution to the differential boundary-layer equations of motion and energy for the unsteady laminar flow of a compressible fluid under the influence of the ideal-fluid expansion-fan pressure gradient is presented. Solutions are given in the form of infinite power series for velocity and local enthalpy functions. The first three terms of each series are numerically evaluated. Validity of the numerical results is restricted to the region near the leading edge of the expansion wave. Results are compared with the results of the expansion-discontinuity analysis of H. Mirels [*NACA TN* 3712, 1956; AMR **10,** Rev. 229], and large qualitative as well as quantitative differences are shown. Singularities in the flow field are discussed in regard to both the finite-width expansion-wave and the line-expansion-wave solutions.

W. Wuest, Germany

4106. Gortler, H., On the calculation of steady laminar boundary layer flows with continuous suction, *J. Math. Mech.* **6,** 3, 323–340, May 1957.

A method for computing steady, laminar, boundary-layer flows by means of a series of tabulated functions, recently published by the author for the case of impermeable walls [title source **6,** 1–66, 1957], is extended to the case of flows with continuous suction. It is shown that this extension is possible, but the additional functions (38 are mentioned) required to solve cases of practical interest are not yet available.

L. Landweber, USA

4107. Herzig, H. Z., and Hansen, A. G., On possible similarity solutions for three-dimensional incompressible laminar boundary layers. II—Similarity with respect to stationary polar coordinates, *NACA TN* 3832, 16 pp., Nov. 1956.

Paper is an extension of previous work by same authors [AMR **10,** Rev. 1176]. Solutions are tabulated for the mainstream flow in stationary cylindrical coordinates for all the laminar, imcompressible, thin boundary-layer flows having similarity with respect to the coordinates in the plane of the surface. Solutions are given for three mainstreams:

(1) An outward flow along radial lines from a stagnation point.
(2) A spiral flow out from (or in toward) a central point.
(3) A circular flow.

Solutions permit treatment of flows with acceleration or deceleration in the radial or tangential directions.

In application, the exact solutions have the difficulty that their boundary layers have no proper leading edge in the finite part of the plane. This investigation terminates with the boundary-layer equations transformed into ordinary differential equations. The numerical solutions of these ordinary equations are not considered.

J. P. Breslin, USA

4108. Michel, R., and Sirieix, M., A new method of triggering boundary-layer transition (in French), *C. R. Acad. Sci. Paris* **243,** 3, 231–233, July 1956.

In small-scale wind-tunnel tests, it is usual to trigger artificially boundary-layer transition on models in order to simulate high Reynolds number conditions. The authors' results show that the use for that purpose of transverse wires on the model wing surface may appreciably affect the pressure distribution, at transonic speeds. This is avoided by utilizing a series of wires or fences placed in the direction of the free stream around the wing section, the transition being produced by transverse diffusion of turbulence without disturbance to the flow field. Furthermore, interpretation of schlieren flow visualization is facilitated by Mach wavelets originating from the model surface.

J. Lukasiewicz, Canada

4109. Strscheletzky, M., A contribution to the study of the hydrodynamic equilibrium of flows (in German), Heidenheim, Germany, Voith Research and Design no. 2, 1–8, 1957.

The separation of the boundary layer from the wall surface is the result of a retardation of the boundary-layer flow and is due to the viscosity of the flowing liquid. Such separation is funda-

mentally different from the discontinuities, which are set up by the action of inertial forces (centrifugal forces) in flows and are dependent on the hydrodynamic equilibrium of the flowing liquid. Such discontinuities in the velocity field separate an "intact" flow from those zones which, while filled with liquid, are outside of the "intact" flow. Such zones are designated as zones of "inertial separation of flow" ("Trägheitsablösungen").

By means of the fundamental principles of mechanics the numerical study of the phenomena of inertial separation of flow is brought back to the analysis of the hydrodynamic equilibrium of a flowing liquid. The method, developed in this way, of the "least action" of flows allows calculation of the form and the extent of discontinuities that delimit the "intact" flow and correspond to their hydrodynamic equilibrium. This method also allows dealing with the problem of flows that, with given delimitations (walls), possess the hydrodynamic equilibrium and proceed without any phenomena of inertial separation of flow.

As examples for the results obtained so far in the computation of and the experimental checks on the hydrodynamic equilibrium of flows are mentioned (a) whirls in cylindrical pipes and diffusors; (b) flows in bends.

The calculations and the test results clearly show that the hydrodynamic equilibrium of incompressible flowing fluids and the form and extent of the separation zones, which are set up as a result of the effect of inertial forces (centrifugal forces), depend on the velocity field of the flow and not on the pressure head.

The forms of inertial separation of flows which are set up in case (a), as calculated and as measured, are in full agreement if the distribution of the whirls in the "intact" flow is the same for the practical experiment and for the calculation.

The photos of air flows in 90° bends are particularly striking. The flow in a bend (Fig. 7) distinctly shows an inertial separation of the flow from the inner wall. After checking the hydrodynamic equilibrium of the flow involved, using the method of the "least action," the inner wall of the bend has been changed, while the mean-velocity flow has virtually been retained unchanged. The flow in the modified bend does not show any phenomena of separation.

Inertial separation of flow cannot be influenced or remedied by such usual means of boundary-layer control as acceleration and suction. On the other hand, such separation of flow readily responds to any change of the velocity field of the "intact" flow, since, in such a case, the inertial forces (centrifugal forces)—which are responsible for the phenomena of inertial separation of flow—are changed. From author's summary

Aerodynamics of Flight; Wind Forces

(See also Revs. 3899, 4010, 4059, 4065, 4076, 4078, 4080, 4081, 4088, 4089, 4093, 4124, 4126, 4127, 4185, 4211)

4110. Diederich, F. W., The response of an airplane to random atmospheric disturbances, *NACA TN* 3910, 95 pp., Apr. 1957.

The statistical approach to the gust-load problem has been extended in several respects; basic assumptions retained are: (a) linearity of forces due to smallness of disturbances, motions, and deformations; (b) atmospheric turbulence is homogeneous, axisymmetric, and can be treated as a stationary random process. The effects of lateral variations of the instantaneous gust intensity on the aerodynamic forces are discussed. These forces are applied to dynamic response studies of rigid and flexible airplane in plunge, pitch and roll. Interaction effects of longitudinal, lateral, and vertical gusts on the wing stresses are considered.

H. P. Liepman, USA

4111. Puttock, D. R., Fin-and-rudder loads in a yawing manoeuvre: effect of direct and power assisted rudder movement, *Aero. Res. Counc. Lond. curr. Pap.* 301, 34 pp. + 27 figs., 1956.

The standard equations for lateral motion of aircraft are analyzed for angle of sideslip, fin and rudder loads, and hinge moment, under sinusoidal rudder motion. Rudder frequencies from 0.5 to 1.5 times aircraft frequency in damped yawing oscillations cover all critical conditions. Graphs showing first three maxima of sideslip angle for ranges of lateral damping parameters and rudder frequency are given. Derivation of approximate formulas for loads and moments permits solutions to be read from a sequence of graphs.

Sideslip and load maxima occur at frequencies close to damped resonant conditions. Hinge moments occur at higher frequencies depending on values of aerodynamic parameters. For design maneuvers defined by maximum hinge moment or pedal forces, sideslip angles and fin-rudder loads reach absolute maxima at frequencies considerably below the damped resonant frequency. Design requirements (AP 970) calling for rudder movement at damped resonant frequencies up to a specified pedal force do not necessarily give critical loads or sideslip angles; maxima occur at frequencies slightly below resonance. The effect of a power unit in the rudder system is discussed at length, usually under the assumption that rudder movement is limited so that design conditions cannot be entirely realized. E. T. Welmers, USA

4112. Scherer, M., Delaveault, P., and Riou, F., Determination of aerodynamic coefficients and the efficiency of control in flight from the response to harmonic inputs initiated by the pilot (in French), *Rech. aéro.* no. 56, 13–20, 1957.

4113. Stancil, R. T., Comments on the Lagrangian multiplier in drag minimization, *J. aero. Sci.* **24,** 5, 388–389, May 1957.

4114. Behrbohm, H., Derivation of Euler's differential equations for the optimum rate of climb in a vertical plane for an aircraft operating with the end conditions varying (in German), *Z. Flugwiss.* **4,** 12, 373–382, Dec. 1956.

4115. Payne, P. R., A general theory of helicopter rotor dynamics, *Aircr. Engng.* **26,** 306, 247–251, Aug. 1954.

From equations of moment equilibrium about flapping hinge of a rigid rotor blade, explicit expressions for the zeroth and first harmonic coefficients (a_0, a_1, b_1) of the flapping angle are obtained. Explicit results are based on blades with linear taper and linear twist. By neglecting higher harmonics, analysis is kept comparatively simple. The usual blade-element theory is used, and induced velocity is assumed constant over rotor disk; effect of nonuniform downwash is briefly indicated. Results of numerical example based on an actual rotor are given in detail.

M. Morduchow, USA

4116. McCormick, B. W., Jr., On the initial vertical descent of a helicopter following power failure, *J. aero. Sci.* **23,** 12, 1125–1126 (Readers' Forum), Dec. 1956.

Aeroelasticity (Flutter, Divergence, etc.)

(See also Revs. 4080, 4115, 4212)

4117. Kussner, H. G., Aeroelastic problems in airplane technology (in German), *Mitt. Max-Planck-Inst. Strömungsforschung,* no. 14, 32 pp., 1957.

Expanded text of a lecture covering the essentials of aeroelasticity in a general presentation. Various aeroelastic phenomena are described. Experimental solution by models is briefly discussed. The general equations of aeroelasticity are deduced for a

plate-like wing and extended to the case of a whole airplane. A summing up of the theory of nonstationary aerodynamic forces on wings is given.

A procedure for the approximate solution of the equations of aeroelasticity follows. The experimental determination of the deformation tensor and of the fundamental modes on the airplane is described. The deformation is then represented in generalized coordinates and the equation of motion is written in the form of Lagrange's equation. The approximate solution is then presented in the Rayleigh-Ritz or Galerkin form.

A procedure for the approximate evaluation of the aerodynamic forces is also described. The example for a supersonic wing is given.

An example of application to the analysis of flutter of a trapezoidal wing is given. The critical velocities for the wing with and without aileron are presented in diagrams, including the cases of mass and aerodynamic unbalances. Finally, criteria for prevention of flutter are indicated. C. Riparbelli, USA

4118. Kussner, H. G., Aeroelastic problems of airplane design, *NACA TM* 1402, 51 pp., Nov. 1956. (Translation from *Z. Flugwiss.* **3**, 1, Jan. 1955).

See AMR **8**, Rev. 3162.

4119. Woods, L. C., Aerodynamic forces on an oscillating aerofoil fitted with a spoiler, *Proc. roy. Soc. Lond.* (*A*)**239**, 1218, 328–337, Mar. 1957.

A theoretical investigation is given of a thin airfoil performing small harmonic oscillations in an incompressible fluid with flow separation on the upper surface. Separation point is assumed fixed and pressure on the free streamlines is assumed constant. Formulas are obtained for the pressure distribution, lift, and moment. The effect of separation on the damping derivatives is illustrated in a number of graphs. The figures show that in almost all frequency ranges there is a loss of direct damping for plunging and pitching oscillations which increases with increasing extent of flow separation. Author points out theory cannot be applied to the problem of stalled flutter unless the separation point can be shown to be fixed. S. Levy, USA

4120. Jones, D. S., The unsteady motion of a thin aerofoil in an incompressible fluid, *Comm. pure appl. Math.* **10**, 1, 1–21, 1957.

Author treats the problem of a harmonically oscillating airfoil in incompressible flow. Airfoil shape is approximated by a polynomial with constants determined so that the mean position of the chord is approximately zero at all times. By properly accounting for the wake, problem is solved by means of Mellin transforms. Formulas for pressure distribution, downwash, etc., are developed. An alternate method of obtaining the same formulas by means of reverse-flow theorems is discussed.

H. N. Abramson, USA

4121. Targoff, W. P., and White, R. P. Jr., Flutter model testing at transonic speeds, *Aero. Engng. Rev.* **16**, 6, 58–62, June 1957.

Flutter research on reflection plane models of straight, swept, and delta wings in a 3 × 4-ft transonic test facility is described. From author's summary

4122. Sylvester, M. A., and Baker, J. E., Some experimental studies of panel flutter at Mach number 1.3, *NACA TN* 3914, 25 pp., Feb. 1957.

Experimental studies of panel flutter were conducted at a Mach number of 1.3 to verify the existence of this phenomenon and to study the effects of some structural parameters on the flutter characteristics. Thin rectangular metal plates were used in these studies and were mounted as a section of the tunnel wall. Most of the data were obtained by using aluminum-alloy panels, although a few steel, magnesium, and brass panels were also used. Different materials with various thicknesses and lengths were used to determine the effect of these parameters on panel flutter. The experimental program consisted of three phases: (1) panels clamped front and rear with tension, (2) initially buckled panels clamped front and rear, and (3) buckled panels clamped on all four edges.

Panel flutter was obtained under controlled laboratory conditions and it was found that, at the flow conditions of these tests, increasing tensile forces were effective in eliminating flutter, as were shortening the panels or increasing the bending stiffness. No apparent systematic trends in the flutter modes or frequencies could be observed, and it is significant that the panel flutter sometimes involved higher modes and frequencies. The presence of a pressure differential between the two surfaces of a panel was observed to have a stabilizing effect. Initially buckled panels were more susceptible to flutter than panels without buckling. Buckled panels with all four edges clamped were much less prone to flutter than buckled panels clamped front and rear.

From authors' summary

4123. Lauten, W. T., Jr., and Nelson, H. C., Results of two free-fall experiments on flutter of thin unswept wings in the transonic speed range, *NACA TN* 3902, 20 pp., Jan. 1957.

Flutter data in the transonic speed range for four nearly identical, thin, unswept wings have been obtained by the bomb-drop method. Two wings fluttered at a Mach number of 0.85, one wing fluttered at a Mach number of 1.03, and the other wing fluttered at a Mach number of 1.07.

The experimental flutter speeds were compared with values calculated by using a method of analysis which includes the effect of mode shape and is based on two-dimensional flow. The calculations were made for Mach numbers ranging from 0 to 1.43, including a Mach number of 1.0. The experimental flutter speeds, in general, exceeded the calculated values. There is an indication that the critical flutter region is moved to a higher Mach number range when thin wings are used. From authors' summary

4124. Goland, L., and Perlmutter, A. A., A comparison of the calculated and observed flutter characteristics of a helicopter rotor blade, *J. aero. Sci.* **24**, 4, 281–290, 320, 1957.

Paper presents Rayleigh-type analysis with two degrees of freedom allowing for blade flapping and blade torsion plus pitch. Aerodynamic forces are assumed stripwise two-dimensional with Theodorsen unsteady lift factor $C(k)$ averaged over blade span. Physical admissibility of this type of aerodynamics is not extensively discussed. Reviewer remarks that zero-speed-of-flight case of unloaded helicopter rotor is aerodynamically singular in that blades re-enter their own wake. Theory to this case recently became available from Timman [see, e.g., E. van Spiegel: The aerodynamic forces on oscillating rotor blades, Proc. Second European aero. Congr. 1956, p. 71.1]. Comparisons with experiments found to be generally satisfactory are to be distrusted for reasons mentioned for case of unloaded rotor.

J. H. Greidanus, Holland

4125. Carter, A. D. S., A theoretical investigation of the factors affecting stalling flutter of compressor blades, *Aero. Res. Counc. Lond. curr. Pap.* 265, 13 pp. + 9 figs., 1956.

A general expression was derived for the critical stall flutter speed of cascades by equating the work done per cycle by the aerodynamic force and that done by the damping force under the assumptions of no aerodynamic hysteresis and certain phase lag of the aerodynamic force on the blade behind the motion of the blade. The critical flutter speed is then expressed as the product of an aerodynamic constant, the maximum blade thickness, the blade damping (in logarithmic decrement), the natural frequency of the blade and the density ratio between the blade material and the air stream.

For blades of a fixed height, this expression implies that the critical flutter speed would vary as the square of the maximum blade thickness. Reasonable correlation with test results was obtained on this variation, although a slight departure from the second power proposition was noted when blade incidence was changed. Further work on the effect of blade frequency due to change of blade height and the effect of air density will be reported later. C. C. Wan, USA

4126. Lambourne, N. C., and Chinneck, A., The flutter properties of a simple aero-isoclinic wing system, *Aero. Res. Counc. Lond. Rep. Mem.* 2869, 16 pp., 1956.

Subject system (which consists of a sweptback wing elastically designed so that lifting loads do not affect the aerodynamic incidence) was studied theoretically and experimentally. The results show that this particular system is not free from flutter and that, under certain conditions, the flutter speed may be quite low.
B. Smilg, USA

4127. Wittmeyer, H., and Templeton, H., Criteria for the prevention of flutter of tab systems, *Aero. Res. Counc. Lond. Rep. Mem.* 2825, 44 pp., 1956.

An investigation has been made into the flutter characteristics of an idealized tab system in which the three degrees of freedom normal translation of the lifting surface, rotation of the control surface, and rotation of the tab—are represented. Specific cases of this idealized system represent similar idealized forms of the standard trimming, spring, servo, and geared tab systems. From a consideration of the relationships existing between the systems, criteria are applicable to the stick-fixed condition (in the case of spring and servo-tabs), to the case with no aerodynamic balance on either control surface or tab, and to the case where the control surface is statically balanced about its hinge.

Comparison is made between the criteria for spring-tabs and the existing Collar-Sharpe criteria. Design implications are deduced from the criteria for spring-tabs, and the general application of the criteria to actual systems is considered in some detail.
From authors' summary by K. Stewartson, England

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 4076, 4150, 4153, 4154, 4172, 4199, 4216, 4219)

Book—4128. Finch, V. C., Jet propulsion. Turboprops, Palo Alto, Calif., The National Press, 1950, xvi + 256 pp.

This book is a collection of material from available unclassified information which is intended to present a teachable arrangement of principles, assumptions, standards and practices as applied to propellor turbines. It is a book of engineering applications and fundamentals which are recommended by the Engineering Council for Professional Development, a body assigned the duty of accrediting engineering courses in the U.S.A., as the tools of the turboprop student. It is produced by offset printing, permitting easy revision, and, so, descriptive data on present day turboprops has been much used to teach current design practice. Many illustrative examples with complete solutions are included in the text, and an offer is made of an abundance of problems with answers, which will be forwarded free to instructors who use the book.

The text draws extensively on English engines and technical publications for its information and examples, little appearing from American sources. Each chapter is followed by a relevant list of references and the index is guaranteed to be a detailed guide to the contents, having been prepared by a librarian. The first three chapters cover the applications, limitations, and possibilities of the turboprop, its mechanics and performance evaluation. Fundamental design considerations is the fourth, while the fifth and sixth are aircraft gas-turbine fundamentals and blade path. Following on there is design of the individual gas-turbine stage, turbine-blade ring analysis, turbine-blade design, two-dimensional flow through cascades of turbine blades, high-temperature alloys and turbine-blade stress analysis, and turbine disk design and stress analysis. Chapters thirteen and fourteen deal with combustion and combustion efficiency. The last three chapters cover the fluid dynamics of compressors and the design of centrifugal and axial flow compressors.

While a list of symbols is given at the end of the book, this is not fully comprehensive and reference has to be made to the text to surely define the meaning given to any symbol in a given equation. This is a book that, while not being a complete design handbook, gives a useful working introduction to a subject which is growing and changing continuously. It can be recommended to students interested in propellor turbines as a useful basis to promote understanding of the physical processes involved and the design philosophy behind them.
A. F. W. Langford, Australia

4129. Beke, A., Analytical investigation of the effect of water injection on supersonic turbojet-engine-inlet matching and thrust augmentation, *NACA TN* 3922, 25 pp., Jan. 1957.

The results of cooling the inlet air by evaporation of injected water in the diffuser were calculated and applied to the matching of inlet performance to engine requirements. Whereas a fixed-geometry inlet must spill some 50% of the total possible flow at Mach 2 to match engine requirements, the same inlet with water injection can be matched with no spillage. The drag associated with spillage is thus avoided.

Water injection is compared with fixed-geometry, bypass, and translating-spike arrangements for inlet-engine matching. Up to 56% higher thrusts are obtainable with water injection, but only at the expense of a greater total fluid (water plus fuel) consumption rate. Water injection also permits greater speeds and altitudes for engines presently limited by temperature, since the inlet air is cooled by the water; e.g., speed increases from Mach 2.0 to 2.6 and cruise altitude from 55,000 to 67,000 ft. Author suggests that a combination of bypass and water-injection matching might be the best solution. C. L. Coldren, USA

4130. Judd, J. H., and Trout, O. F., Jr., Free-jet tests of a 1.1-inch-diameter supersonic ram-jet engine, *NACA TN* 3906, 24 pp., Feb. 1957.

A 1.1-inch-diameter hydrogen-burning ramjet engine having a design Mach number of 2.13 was tested in a free supersonic jet. Performance characteristics of the engine are presented for a Mach number range from 1.42 to 2.28. A comparison of the performance characteristics of the engine with combustion-chamber lengths of 3.33 and 1.51 engine diameters was made at a Mach number of 2.06.

The maximum thrust coefficient obtained for the ramjet engine with the 3.33-diameter combustion chamber was 0.905 at a Mach number of 2.06 and a fuel-air ratio of 0.034. The lean burnout of the engine occurred at a fuel-air ratio of 0.008 for all Mach numbers and the rich burnout at 0.082 at a Mach number of 1.42. There was smooth burning over the entire fuel-air-ratio range.

Shortening the combustion-chamber length from 3.33 diameters to 1.51 diameters reduced the thrust coefficient from 0.905 to 0.236 at a fuel-air ratio of 0.034 and a Mach number of 2.06. The smoothness of combustion was unaffected by the change in combustion-chamber length. From authors' summary

4131. Herrig, L. J., Emery, J. C., and Erwin, J. R., Systematic two-dimensional cascade tests of NACA 65-series compressor blades at low speeds, *NACA TN* 3916, 223 pp., Feb. 1957.

Paper presents recently declassified results of a two-dimensional low-speed porous-wall cascade tunnel investigation to

establish the performance of the NACA 65-series compressor blade sections over the useful range of inlet angle, solidity, and section camber. Design points for optimum high-speed operation are presented. The loading limitation is determined for some conditions. Trends of section operating range with increasing section camber are determined for the four inlet angles tested.

J. V. Becker, USA

4132. Louis, J. F., and Horlock, J. H., A graphical method of predicting the off design performance of a compressor stage, *Aero. Res. Counc. Lond. curr. Pap.* 320, 9 pp. + 12 figs., 1957.

Using actuator disk theory, a three-row compressor stage—guide vanes, rotor and stator—is graphically analyzed. Method allows mechanism of stage stall to be exhibited. Detailed example of off-design performance of free-vortex stage is described, and operating characteristics obtained. Technique assumes distribution of tangential vorticity with radius at exit from row is unchanged by presence of nearby rotor. Method determines static pressure at various radii which satisfy radial equilibrium condition downstream of following rotor row at various flow coefficients; same method applies for stator flow, and following stages. Comparison with experiment indicates reasonable agreement, except for differences attributable to use of two-dimensional cascade data, boundary layer, tip leakage, and secondary flow. Method may allow preliminary choice of best stage design to be made, and is a worthwhile contribution to design literature.

B. W. Augenstein, USA

4133. Kopeetsky, V. V., The theory of the Prandtl correction for a ducted propeller (in Russian), *Trudi Leningr. Korablestroit. in-ta* no. 14, 90–97, 1954; *Ref. Zh. Mekh.* 1956, Rev. 3670.

Examination of the two-dimensional, noncirculating flow of a fluid through an infinite series of plates of identical width equally spaced parallel to each other between two parallel walls. The plates are placed perpendicularly to the walls and at equal distance from them.

Application of the method of mirror transformation enables the problem to be reduced to the investigation of the flow around a two-dimensional cascade with a "double-entry," the complex potential being found to be expressed by an elliptical Jacoby sine. The results thus obtained are used to determine the optimum distribution of the circulation along a propeller blade working in a duct of given radius. This is performed by a method analogous to that of Prandtl, suggested by the latter for determining the most favorable distribution for a circulation about a propeller blade working in a free flow. Author suggests determining the correction for finite blade number by Goldstein's method [*Proc. roy. Soc. Lond.* **123**, 440–465, 1929] instead of by Prandtl's.

Courtesy Referativnyi Zhurnal N. N. Babaev, USSR
Translation, courtesy Ministry of Supply, England

4134. Davis, H., Equivalent performance parameters for turboblowers and compressors, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–122, 6 pp.

Author defines the parameters of equivalent performance for turbocompressors and shows how they may be used for correlation of shop and field testing with design information. Three classifications of correlation are defined with different degrees of correlation accuracy. The first class includes cases where the correlation error is negligibly small, even when the test fluid is different from the design fluid. The second class includes cases where the correlation accuracy is reasonably good. The third class offers no satisfactory correlation conditions. It is proposed that similar concepts of correlation be recognized by and incorporated into the appropriate Power Test Code for turbocompressors. From author's summary

4135. Turner, J. R., An investigation of the end-wall boundary layer of a turbine-nozzle cascade, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–132, 7 pp.

As part of a research program aimed at an explanation of the low efficiencies measured near the casings of turbines, an experimental investigation of the flow through a rectilinear cascade of turbine nozzles was conducted to study the effects of the end-wall boundary layer on the flow pattern through the nozzles. Secondary flows in the boundary-layer fluid produce an accumulation of low-energy fluid in the cascade exit plane that is considerably different from the flow field of the two-dimensional wakes. To describe the effects of the secondary flows, detailed data are included showing blade-pressure-distribution variations through the end-wall boundary layer, flow directions, and total and static pressure at cascade discharge, both with and without an inlet boundary layer on the end wall. From these data, qualitative conclusions have been drawn concerning the nature and origin of these low-energy accumulations. The most significant of these conclusions are (*a*) that the end-wall boundary-layer behavior inside the nozzle passage is essentially independent of the boundary layer entering the cascade; and (*b*) the low-energy fluid which appears in the suction-surface, end-wall corner at cascade discharge has its origin only in the end-wall and suction-surface boundary layers. From author's summary

4136. Blake, L. R., A. C. and D. C. conduction pumps for liquid metals. Parts I, II, *Engineer, Lond.* **202,** 5257, 541–544; Oct. 1956; **202,** 5257, 572–576, Oct. 1956.

An examination is made and the chief design features established of the d c conduction pump and of the mains-frequency and low-frequency a c conduction pump, including types with combined low-voltage transformer. Special consideration is given to their behavior at high output powers with liquids such as bismuth. Performance figures of typical designs are given and the relative merits of the different types of conduction pump are outlined. It is suggested that the low-frequency a c conduction pump is a useful alternative to the d c conduction pump and homopolar generator. From author's summary

4137. Kochkarev, A. Ya., An investigation of the flow and flow characteristics in the flow section of a hydraulic reversing torque converter (in Russian), *Trudi Leningr. politekh. in-ta* no. 177, 5–20, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3627.

The results are communicated of an experimental investigation into the velocity and pressure distribution of the flow section of a hydraulic torque converter (hydraulic clutch) made in the laboratory for hydraulic machines of the Leningrad Polytechnic Institute. The measurements were made in triply-ducted, cylindrical pipes of a total diameter of 4 mm and ducts of 0.6-mm bore. The pipes were located at three cross sections: between the pump and the guide (stator) blading; between the guide blading and the turbine (rotor); between the turbine and the pump. In each cross section the measurements were made at five points.

Evaluation of the results has determined the following characteristics: the absolute velocity with its peripheral and meridional components, total and static head, volume of circulation flow, momentum, and energy. It is found that the streamline theory can be used for the calculation of a hydraulic transformer only in the capacity of a first approximation and only in conditions in which no flow reversal takes place. In respect to the deflection of the flow from the blade direction the best agreement with the experimental data is provided by the formula of G. F. Proskura ["Hydrodynamics of turbomachines," 1934]. The angle of attack in the different regions of the converter in each case depends on the working flow conditions. The static-pressure distribution across the flow agrees quantitatively with the results calculated by

Kudryavtsev's method [A. P. Kudryavtsev, "Design, construction and testing of hydraulic turbotransmissions," Mashgiz, 1947].
Courtesy Referativnyi Zhurnal M. A. Mostkov, USSR
Translation, courtesy Ministry of Supply, England

4138. Wiggins, J. W., The use of solid propellant engines for achievement of super velocities, *Jet Propulsion* **26,** 12, 1084–1087, 1090, Dec. 1956.

A review of the analytical relationships determining the velocity of a missile is presented. The effect of engine efficiency for low burned velocities and super velocities is discussed. The efficient staging for achieving velocities higher than can be achieved for a single stage is discussed. The large growth factors inherent when low-performance engines are used for achievement of super velocities and the corresponding reduction of missile gross weight when higher performance rocket systems are used are illustrated. The basic case-bonded solid-propellant rocket system and its characteristics which provide the high performance necessary for the achievement of super velocities are explained. New case materials and insulating materials are discussed which can be adapted to such a rocket system for improvement of engine weight efficiency. From author's summary

Flow and Flight Test Techniques

(See also Revs. 4027, 4071, 4088, 4105, 4108, 4234)

4139. Batmanovsky, E. A., An automatic instrument for air-flow velocity measurements (in Russian), *Gorky Zh.* no. 8, 61–62, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3775.

An instrument is described for measuring and recording the velocity of air currents in mine workings for the purpose of obtaining a correct picture of the distribution of the air currents in the workings, i.e., controlling the efficiency of the ventilating arrangements. The possibility of using cup anemometers, hot wire anemometers, or glow-discharge anemometers is restricted, both by the insufficient robustness and short working life of such instruments in mine conditions, and by safety considerations. The instrument described is an anemometer of the thermal type in which the hot wire is replaced by a thermal resistance of the MMT-1 type. Two such thermal resistances are coupled as two arms of a bridge circuit, one of these being enclosed in a casing with apertures for the admission of the airflow to be measured, while the second is enclosed in an airtight casing. This makes the instrument sufficiently sensitive to the airflow velocity while considerably reducing the influence of the ambient temperature. The measurements are effected by a self-balancing electronic bridge instrument, type EMD-17, with appropriately modified input circuits.

Tests of the instrument in the laboratory and in a nonferrous mine showed that it can measure inflow velocities within 0–8 m/sec with a sensitivity down to 5 cm/sec, and an indicating error not exceeding 2%. Variations of ± 20% in the supply voltage, temperature fluctuations of the air stream between + 10 to + 30°, and humidity variations up to 90% do not affect the instrument error. Release of the first trial series of these instruments for test under field conditions underground is planned. Ya. I. Merson, USSR
Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4140. Hack, H. R. B., An automatic null method recording manometer, *J. sci. Instrum.* **34,** 7, 280–282, July 1957.

4141. Taylor, C. F., Mass flowmeter for in-flight refueling, *Trans. ASME* **79,** 5, 1039–1042, July 1957.

A new mass flowmeter for in-flight refueling of jet aircraft is described. This flowmeter incorporates very large capacity in a compact rugged unit of unusually high accuracy. Other features are lightweight, low pressure drop, no rotating fluid seals, and fast response to sudden changes in fuel flow rate. This has been achieved by applying the angular momentum principle to obtain a mechanical torque that is linearly proportional to mass rate of flow. From author's summary

4142. Seemar, G. H., New developments in area meters, *Instrum. and Automat.* **30,** 2, 256–257, Feb. 1957.

Refinements in production technique—ultrasonic impact grinding, precision bore tubing, careful surface finish control—make possible reproducible orifices in area meters and reliable repeatability of measurement. From author's summary

4143. Leck, J. H., and Martin, C. S., Feedback controlled heat conductivity gauge for measuring pressure in vacuum systems, *Rev. sci. Instrum.* **28,** 2, 119–121, Feb. 1957.

Paper describes a simple feedback circuit for the hot-wire Pirani gage. This gage is used for measurement at low pressures where the heat conducted away from a thin hot wire is a function of the gas pressure. The wire is included in a Wheatstone bridge circuit which serves both to heat the wire and to measure its temperature. In the circuit described here the heat input is adjusted automatically so as to keep the wire temperature approximately constant over a wide range of pressure changes. This is achieved by supplying the power from a magnetic amplifier which is controlled by the wire temperature, a fall in temperature increasing and a rise in temperature decreasing the power supply.

In this way pressure measurements can be made over the range zero to 3 mm Hg with wire temperatures of the order of 50 to 100 C by using either the feedback signal or the power output from the amplifier to give a measure of the pressure.

From authors' summary

4144. Korkegi, R. H., An aerodynamic means of static-pressure compensation for transonic and supersonic aircraft, *Aero. Engng. Rev.* **16,** 4, 64–68, Apr. 1957.

Free-stream pressure measurements in high-speed flight are difficult due to compressibility effects. It is shown that a judicious choice of complementary (probe and body) geometrics yields compensating pressure field variations. The resulting sensor pressure is considerably less dependent on Mach number for an illustrative experimental check ($0.5 \leq M < 1.1$). Probe geometry was experimentally determined. J. R. Baron, USA

4145. Weltmann, R. N., and Kuhns, P. W., The use of an automatic viscometer for the study of lubricant flow, *Lubrication Engng.* **13,** 1, 43–50, Jan. 1957.

Many lubricants, such as greases, are non-Newtonian and time-dependent materials. The flow behavior of such materials is studied from flow curves which are measured over a wide range of rates of shear and under fully controlled flow conditions of shear rate, applied time, temperature, and pressure. In this paper, these flow curves are measured with a rotational concentric-cylinder viscometer which is so designed that the flow curves can be recorded directly and that the flow conditions of shear rate and time can be controlled automatically. Flow curves, obtained under different controlled flow conditions, are presented for a diester oil and two lubricant greases. An analysis is made from the flow curves of the effects of the flow properties and their variations with time, rate of shear and temperature on bearing lubrication, and on the transport of lubricants in pipe lines.

From authors' summary

4146. Humphreys, F. E., and Stone, N., Measurement of high viscosities by shearing between parallel plates, *J. sci. Instrum.* **34,** 1, 26–27, Jan. 1957.

Viscosities in the range 10^4–10^7 poises have been measured by shearing thin films between two parallel stainless-steel plates.

In this way frictional heat is rapidly dissipated, temperature being registered by a thermistor. From authors' summary

4147. Derazhne, R. I., Popov, V. P., and Frenkel, Yu. B., Viscometer with automatically recorded ball falling-time (in Russian), *Zavod. Lab.* **21**, 6, 731–733, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3785.

The falling-ball viscometer consists of a glass gage cylinder containing two induction coils at a fixed distance apart connected in two identical oscillator circuits. The passage of the ball past one of these disturbs the equilibrium of the currents, the resulting pulse is amplified and recorded by the flash of a neon tube or by an electrical chronograph.

Circuit diagrams and brief descriptions are given of three variants of the instrument: with neon tube, with two electromechanical relays and electrical chronograph, and with an electronic relay and electrical chronograph. The last form insures the highest accuracy of measurement. The instrument is suitable for viscosity measurements in nearly all, including opaque, liquids.

Courtesy Referativnyi Zhurnal S. A. Regirer, USSR
Translation, courtesy Ministry of Supply, England

4148. Anderson, J. R., and Treadgold, D., Force and moment measurements on a conical body and a rectangular wing, separately and in combination, at Mach number 1.94, *Aero. Res. Counc. Lond. Rep. Mem.* 2864, 25 pp., 1956.

Results are given of wind-tunnel measurements at $M = 1.94$ of lift, drag, and pitching moment at small angles of incidence on two cones, three rectangular wings, and on the six derived cone-wing combinations. A description of the tests and a comparison with theory are also included.

The agreement between theory and experiment for the lift of the isolated cones and wings is good; however, for the drag and center of pressure, agreement is a little less satisfactory. The measured lift of the cone-wing combinations exceeded that estimated, whereas the measured center-of-pressure position agreed remarkably well with the estimated position. Agreement between measurement and theory for the lowest aspect ratio wing was improved when a correction was applied for the influence on the cone of the downwash generated by the wings.

An unsuccessful attempt was made to measure the forces and moments on each component of the cone-wing combination independently, while under the influence of the flow field of the other. From authors' summary

4149. Meyer, R. E., On the measurement of supersonic aerofoil drag by pressure traverse, *Aero. Res. Lab. Melbourne, Austral.* ARL/A 97, 27 pp. + 3 figs., May 1956.

The drag in two-dimensional flow is expressed in terms of the distributions of static and stagnation pressures along a traverse line downstream of the airfoil. Sources of error are discussed with regard to their effect on the accuracy of drag measurement in small tunnels at medium Mach numbers. From author's summary

4150. Schmidt, R., Method for thrust and drag measurement on turbojet engines in flight and on models (in German), *Z. Flugwiss.* **1**, 1, 12–20, June 1953.

With the steady increase in the application of turbojet engines, the problem of measuring thrust and drag of airplanes fitted with turbojet engines has become one of more practical importance. After a theoretical introduction into the physical nature of thrust and drag of an airplane driven by a turbojet, various possibilities are given for measuring these forces on the ground and in the air, and the accuracy of measurements is discussed from the practical point of view regarding simplicity of test equipment. From author's summary

4151. Thom, A., and Klanfer, Laura, Tunnel-wall effect on an aerofoil at subsonic speeds, *Aero. Res. Counc. Lond. Rep. Mem.* 2851, 11 pp. + 6 tables + 11 figs., 1957.

Paper presents a theoretical study of the effect of walls on the subsonic flow past a symmetrical airfoil at zero incidence. Author devises a simple method for determining appropriate correction in which the flow distortion is not taken into account accurately. One or two iterations serve to correct the solution. Examples are presented for an incompressible flow and for a flow at $M = 0.7$. W. Griffith, USA

4152. Mirels, H., and Braun, W. H., Nonuniformities in shock-tube flow due to unsteady boundary-layer action, *NACA TN* 4021, 45 pp., May 1957.

The boundary layer along the walls of a shock tube induces pressure and velocity gradients within the core of the potential flow. These nonuniformities are evaluated herein for shock tubes in which the boundary layer is thin relative to the tube diameter and is either wholly laminar or wholly turbulent. As in previous works, the assumptions are made that the boundary layer action is equivalent to a one-dimensional distribution of mass sources and that the expansion wave has zero thickness. The analysis is thus limited to small pressure ratios. Numerical results are obtained for an air-air shock tube. The spatial and temporal variations in the hot gas region are presented graphically. The calculations enable one to predict the variation of free-stream conditions. W. Wuest, Germany

4153. Andrews, S. J., Jeffs, R. A., and Hartley, E. L., Tests concerning novel designs of blades for axial compressors, *Aero. Res. Counc. Lond. Rep. Mem.* 2929, 22 pp., 1956.

Investigation of the flow between the blade rows in a research compressor with conventional half-vortex blades has shown a rapid state-to-stage build-up of the annulus boundary layer. The axial velocity distribution under these conditions bears no resemblance to the straight-line distribution which is usually assumed in design, so the incidence angles at both root and tip probably give rise to considerable secondary losses.

Two sets of blades were designed therefore, with the object of minimizing these effects. The first set was designed with an increased work input at the root and tip of the blades in order to re-energize the boundary layer and prevent axial-velocity profile deterioration. The second set was designed using as a design assumption a mathematical approximation to the axial-velocity profiles found experimentally at various stages in a conventional compressor.

The results obtained from low-speed tests of the first set of blades show that although the boundary-layer thickness was considerably reduced, this was achieved only at the expense of 2% in maximum efficiency as compared with conventional blades. The drop in efficiency is attributed to the stator blade rows which stall at incidences well below the design value, but the effect is probably not uniquely associated with variable work done.

The blades designed for a variable axial-velocity profile also failed to give an improved performance. The maximum efficiency was 3% below that of the equivalent conventional blades, and the axial-velocity profile, instead of remaining approximately as assumed, deteriorated still further.

It is considered that designing for a poor axial-velocity profile is probably wrong in principle. The variable-work-done blades, however, would almost certainly have succeeded in producing an axial velocity substantially constant over the greater part of the annulus if the work had been symmetrically distributed about the mean radius with a ratio of mean to minimum work of about 1 : 1. Under these circumstances it is likely that there would have been a reduction in secondary losses and an increase in efficiency. From authors' summary

4154. Parshchik, A. S., Experimental investigation of compressor cascades of profiles (in Russian), *Sb. tr. Labor. problem bystrokhod. mashin i mekhanizmov Akad. Nauk SSSR* no. 5, 105–124, 1955; *Ref. Zh. Mekh.* 1956, Rev. 3525.

Data are given of statistical wind-tunnel tests on a series of flat, compressor-blade cascades at low velocities of the incident flow (80 m/sec); cascades were investigated with angles of curvature θ of 15, 30, and 45 deg. The cascade aspect ratio, b/t, were 1.0, 1.33, and 2.0, and the discharge angles of the cascades -15°, 0°, $+15^\circ$, and 30°, respectively.

The cascades were formed of profiles with a chord/thickness ratio of 10%. The coordinates of the original symmetrical profile and the curved profiles are not stated in the paper; for which reason it is not possible to compare author's data with other published wind-tunnel data on cascades.

Each cascade was tested at different angles of incidence varying between -5° and $+15^\circ$.

From analysis of the experimental results author concludes that, for a given cascade interval, every angle of deflection of the flow corresponds to a particular curvature of the centerline of the profile at which the profile losses will be a minimum. This curvature is practically independent of the angle of exit, if $0 < \theta < 45^\circ$. For cascades with exit angles between 0° and 45° and a spacing from unity to two, and with profile curvatures between 15° and 45°, it is recommended to select angles of incidence within the limits of 0° and $+5^\circ$, the greater, the closer the spacing of the cascade. A. I. Bunimovich, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4155. Steininger, D. H., and Bennett, F. D., Interferometric test for *N*-wave flow, *J. fluid Mech.* **2,** 3, 209–236, May 1957.

Paper derives an expression for fringe shifts in interferograms of axially symmetrical flow about a supersonic projectile. The expression pertains to that region several or more diameters from the body where the so-called *N*-wave pressure distribution in the shock waves is realized. The expression can be used as a relatively simple method to check against observed fringe shifts, as a means of determining the regions in which *N*-wave flow actually occurs. Authors apply the method to interferograms of small supersonic projectiles, find that *N*-wave flow and asymptotic shock positions are realized closer to the projectile than previously supposed.

Methods described represent a special-purpose simplification of existing techniques for interpreting interferograms of compressible flow phenomena. E. W. Price, USA

Book—4156. Jones, G. A., Modern applied photography, New York, Philosophical Library, Inc., 1957, vi + 162 pp. $4.75.

4157. Frungel, F., The luminescence of intense spark discharges (in German), *Optik* **3,** 1/2, 128–136, 1948.

Photographing sprays and other rapidly occurring phenomena requires light of high intensity and of short duration which can best be provided by an electric spark discharge. A spark-discharge circuit is described, intended for such purposes, which supplies a light intensity of 10^9 stilb, over a time duration of the order of 10^{-7} sec. Both the light intensity and the duration are measured by oscillographic means; these measuring methods are described. Author designed a circuit whereby an instantaneous light output of 10^8 watt is produced over a time duration of 10^{-8} sec; the data of this are as follows: Capacity = 0.1 microfarad, voltage = 10 to 15 Kilovolt, Self induction = 0.03 microhenry, gas pressure = 5 to 10 atm, using Argon, Krypton or Xenon. Spark gap = 0.2 cm. The circuits used for the measurement of light intensity, of small voltage impulses, and of the time function of light intensity are described in detail. The peak light intensity as a function of gas pressure has also been determined; this shows an increase of light intensity with the increase of gas pressure.

K. J. DeJuhasz, Germany

Thermodynamics

(See also Revs. 3887, 4020, 4054, 4094, 4095, 4128, 4181)

Book—4158. Sabersky, R. H., Elements of engineering thermodynamics, New York, McGraw-Hill Book Co., Inc., 1957, xvi + 318 pp. $7.50.

As an introduction to thermodynamics, book is excellent. The presentation of the fundamental laws and derived relationships is clear, and as rigorous as a simple presentation in an elementary text will allow. In illustrating the application of the principles of thermodynamics, interesting examples from present-day engineering practice are given.

The discussion of thermal equilibrium and temperature falls under the heading *Zeroth Law.* This, to the reviewer, is a commendable step in that it impresses upon the student that, like the first and second laws, thermal equilibrium and the resulting concept of temperature is a physical phenomenon that is verified by ample experience but cannot be proved in any other way. The first and second laws are presented before consideration of the properties of pure substances and perfect gases, again emphasizing nondependence of these laws on particular substances or processes.

A further departure from usual practice is that the basic statement of the second law is that of Clausius rather than the equivalent, but perhaps more elegant, statement of Planck. The student on being introduced to thermodynamics for the first time is more readily able to comprehend that, in effect, heat will always flow from the hotter to the colder of two bodies, than that "a perpetual motion machine of the second kind is impossible," particularly since the latter usually is coupled with considerations of reversible processes and the Carnot cycle. Incidental to this, reviewer believes that the definition of work given earlier in the text is not sufficiently explicit to serve the student in later examination of complicated systems and processes. Heat, also, could perhaps have received more elucidation to emphasize that, contrary to common usage, heat in thermodynamic terminology refers only to that which flows as a result of a difference in temperature.

The problems in the text form an integral part of the presentation. Through these problems many important extensions of the basic laws and concepts are left to the student to develop, a procedure which is likely to create in the student more active interest in the material and a deeper understanding of the subject. On the other hand, this has led to what the reviewer believes to be the only shortcoming of the book, namely, that, having completed the introductory course, the student is left with a text that provides an excellent exposition of the principles involved, but is of somewhat limited value as a reference book in later years. Thus the book will always require parallel reference to the student's own notes, and to other more complete texts.

Several factors such as the chapter on dimensions and units, and the differentiation between gravitational acceleration and the constant of Newton's second law, considerably enchance the value of the book as an introductory text. Furthermore, the short biographical footnotes on the various scientists and engineers who have contributed largely to the present understanding of thermodynamics add vitality and interest to the subject matter, while the somewhat detailed explanatory notes given as part of the title to many of the illustrations, and in connection with various examples, should give the student a better idea of the order of magnitude and significance of the quantities involved.

Regarding the general content of the book, and keeping in mind that it is intended as an introductory text, reviewer believes that

the coverage is adequate for a first course, although perhaps a fuller treatment of mixtures of perfect gases could profitably have been included. The treatment of systems in motion is good, as is the coverage of corollaries of the second law and availability. The chapters on heat engine cycles are well presented, and a separate chapter is devoted to jet-propulsion cycles. The elements of turbine design are well handled, as is the introduction to combustion. Compressible flow is given far more treatment than is usual in texts on introductory thermodynamics, from which it is gathered that the author recommends introducing the student to compressible gas dynamics simultaneously with the introduction to thermodynamics, rather than in a separate course on fluid mechanics. The advisability of this procedure is open to debate.

Notwithstanding its limited reference value as compared to such texts as Mooney [AMR **7**, Rev. 285], the present book is admirable for undergraduates in its lucid and interest-arousing presentation of the basic laws, concepts, and applications of thermodynamics. It has been prepared with great care, and seems to be free of serious printing errors. A. Whillier, S. Africa

Book—4159. Fermi, E., Thermodynamics, New York, Dover Publications, Inc., 1956, × + 160 pp. $1.75.

This edition is an unabridged and unaltered republication of the first edition. Ed.

4160. Heller, L., Contribution to the fight against irreversibilities (in German), *Energie u. Technik* **4**, 9, 381–385, Sept. 1954; **4**, 10, 425–429, Oct. 1954; **4**, 11, 490–494, Nov. 1954.

4161. Ting, T. W., and Li, J. C. M., Thermodynamics for elastic solids. General formulation, *Phys. Rev.* (2) **106**, 6, 1165–1167, June 1957.

A collection of thermostatic formulas involving the coefficients of linear thermoelasticity of solids. Reviewer believes authors are not aware of earlier and more general results [AMR **9**, Rev. 3377]. M. A. Biot, USA

4162. Grossman, L. M., The first law of thermodynamics for a continuous medium in mass motion, *Amer. J. Phys.* **25**, 4, 257–261, Apr. 1957.

The first-law equation, which states that the increment in energy of a closed system is given by the heat and work interactions of the system and its environment, is applied to an elementary system in a continuous medium in motion—in particular, a compressible viscous fluid. Turbulent conditions are not considered. The first result is an expression of the rate of change of the energy of a control volume in terms of heat and work interactions at the control surface. By introducing Gauss' theorem, the same result is expressed as a differential equation. Work terms appear in terms of the stress tensor and the mean hydraulic pressure.

In the opinion of the reviewer, the clarity of the treatment is marred by a failure to observe the Gibbsian definition of work. The result is a calculation of work done by inertia forces arising from acceleration of the region and work done by conservative body forces like gravity with no reference to the relative motion of the observer. J. H. Keenan, USA

4163. Egan, J. J., and Wiswall, R. H., Jr., Applying thermodynamics to liquid-metal fuel reactor technology, *Nucleonics* **15**, 7, 104–106, July 1957.

4164. Simons, J. H., and Wilson, W. H., Surface tension and viscosity of liquids, *J. chem. Phys.* **23**, 4, 613–617, Apr. 1955.

Book—4165. Haase, Rolf, Thermodynamics of polyphase systems [Thermodynamik der Mischphasen], Berlin, Springer-Verlag, 1956, viii + 597 pp. DM 69.

Author's thoroughness in examining all the ramifications of his subject matter makes this an almost complete treatise on thermodynamics. After a review of thermodynamic fundamentals, the conditions for chemical and physical equilibrium are discussed with considerable mathematical rigor. These conditions are then applied to various types of equilibria in one phase or among several phases, and such consequences as the Clausius-Clapeyron equation, boiling point elevation and freezing point depression, solubility products, distribution ratios, osmotic equilibria, emf's of chemical cells, etc., are discussed in detail.

To the relatively small audience of theoretical physical chemists at whom the book is evidently directed, author presents a well-organized and mathematically sound review of well-known principles. To scientists and engineers in general, unfortunately, the extensive use throughout the book of elaborate mathematical terminology and the preoccupation with mathematical detail without any new insights into thermodynamics are likely to be disappointing, if not exasperating. A. W. Gessner, USA

4166. Van Haute, A., and Sage, B. H., Mollier diagrams for water near bubble point, *Trans. ASME* **79**, 5, 1192–1196, July 1957.

In many problems of engineering interest a knowledge of the thermodynamic properties of a mixture of steam and water drops near the bubble point is of value. As there are no detailed Mollier diagrams available for the states with more water than steam, author has drawn some diagrams ranging from pure water to about equal weight of water and steam. Author gives an example of how the diagrams may be used.

For the calculation of the entropy losses author uses Eq. $dH/dS = \pm T/\alpha$, where H is specific enthalpy, S specific entropy, T absolute temperature, α a number to be determined from experiments. O. H. Faxen, Sweden

4167. Potter, J. H., Steam calorimetry, *Combustion* **29**, 1, 51–55, July 1957.

The art and science of steam calorimetry is reviewed. Descriptions and equations are presented for the principal types of steam calorimeters. The importance of calorimetry is considered in terms of industry and engineering education.

From author's summary

4168. Ray, J. D., Heat of water vaporization as a chemical calibration standard for solution calorimetry, *Rev. sci. Instrum.* **27**, 10, 863–864, Oct. 1956.

A simple method for calibration of calorimeters used in solution calorimetry has been devised. The heat of vaporization of water is taken as a chemical standard for this process and shown to be unaffected by the speed and pressure employed in pumping it out of the evaporator described. From author's summary

4169. Kelsey, K. E., and Clarke, L. N., The heat of sorption of water by wood, *Austral. J. appl. Sci.* **7**, 2, 160–175, June 1956.

The heat of wetting of the ground wood of *Araucaria klinkii* Lauterb (klinki pine) has been measured from a number of initial moisture contents and at three temperatures, and integral and differential heats of sorption have been obtained from the results. The effect of particle size on the heat of wetting of completely dry wood has also been investigated.

Using collateral measurements of the sorption isotherm at one temperature, it is shown that the dependence of the differential heat of sorption on relative vapor pressure for wood is similar to that reported by other workers for cotton and other forms of pure cellulose.

It has been found that the integral heat of sorption is dependent on temperature at all moisture contents greater than approximately 0.12 g/g, the heat evolved on sorption decreasing with an increase in temperature. It appears that the heat of sorption is independent at low moisture contents.

It is shown that as a result of the variation in the heat of sorption with temperature, the specific heat of the wood-water aggregate will be greater than that calculated from the specific heats of the pure components using the relation which applies for simple mixtures. From authors' summary

4170. Lendorff, B., Burkhard, G., and Wirz, K., Reheat applied to turbines of high output, *Escher Wyss News* **29,** 2, 28–39, May–Aug. 1956.

4171. Szaday, R., Control of back pressure of steam turbines (in Hungarian), *Magyar Energiagazdaság* **9,** 3, 107–112, Mar. 1956.

4172. Melan, H., Gas-turbine steam-gas process (in German), *Motortech. Z.* **18,** 6, 175–177, June 1957.

Proposed Pauker power plant includes two or more gas-turbine plants having turbines in series with interposed combustion chambers, so that isothermal expansion process is approximated. Exhaust from last gas turbine supplies heat to steam boiler before discharge to atmosphere; steam is condensed and used again after expansion in steam turbine. Best application is in large stationary installations where useful output is shaft power; assertion is made that high efficiencies will alleviate condition of increasing fuel demands and decreasing fuel supplies. However, present paper treats only theory of how output and efficiency depend on interstage reheat; no numerical values are given. Results are presented as formulas and three-dimensional graphs for one stage of reheat.

Although theory is of interest, reviewer believes addition of well-founded numerical values would be more effective in promoting active development of such plants.

C. W. Smith, USA

4173. Oehmichen, M., The specific output in open cycle gas turbines (in German), *Motortech Z.* **18,** 6, 177–179, June 1957.

Heat and Mass Transfer

(See also Revs. 3887, 3907, 3908, 3939, 3940, 3941, 3990, 4069, 4096, 4097, 4101, 4104, 4105, 4128, 4159, 4163, 4165, 4166, 4226)

Book—4174. Bosworth, R. C. L., Transport processes in applied chemistry, New York, John Wiley and Sons, Inc., 1956, x + 387 pp. $12.

This book presents a fundamental and unified characterization of the three basic transport processes on which chemical engineering is based, i.e., heat, mass and momentum transfer. In the first portion, generalized mathematical expressions descriptive of the various transport-process mechanisms are developed and discussed. This is followed by sections on convective and radiative transfer, and molecular and turbulent motion. Implications of irreversibility, feedback and chemical similarity are also discussed. References to appropriate papers are used extensively.

The material is presented at an advanced level and should be most interesting to the theoretical chemical engineer well versed in mathematics. It is excellent as a theoretical digest of the physical phenomena underlying the science of chemical engineering in that it is so complete in its coverage of the field. The approach is purely scientific, however, and is not directly adaptable to the everyday problems encountered by the practicing engineer.

M. Baker, USA

4175. Vernotte, P., and Ribaud, G., Applications of analytical and numerical methods in heat transfer (in French), *Publ. sci. tech. Min. Air, France* no. 319, 344 pp., 1956.

This is a detailed and discursive review of some numerical methods and convenient transformations in the analysis of some specific boundary-value problems in heat conduction. The generic comments and the relatively complete step-by-step accounts are both pedagogically useful, although the report is rather free of references. S. Corrsin, USA

4176. Duberg, J. E., Some NACA research on effect of transient heating on aircraft structures, *Trans. ASME* **79,** 5, 1014–1018, July 1957.

A brief presentation is made of some of the radiant-heating apparatus developed by the National Advisory Committee for Aeronautics (NACA) to simulate aerodynamic heating of aircraft structures. Some results of the effects of thermal stresses on the stiffness and deflection of aircraft structures are demonstrated by tests incorporating the radiant-heating apparatus.

From author's summary

4177. Bartas, J. G., Gas-side wall temperatures in rib-backed liquid-cooled combustion chambers, *Jet Propulsion* **27,** 7, 784–786, July 1957.

Analytical method is presented for estimating temperature distribution along the axis of a reinforcing rectangular rib in a combustion chamber cooled by a liquid. This has the purpose of predicting the occurrence of potential hot spots. By making conventional assumptions about the boundary conditions the problem is reduced to the solution of conduction equation. The original geometry is transformed by conformal mapping into a one-dimensional problem in a complex plane. The numerical solution is represented in the form of dimensionless working diagram from which the temperature distribution along the rib axis as a function of the rib and wall dimensions can be determined. An illustrative example is worked out.

Reviewer believes that once the author committed himself to the method of conformal mapping the transition from actual wall-and-rib geometry should have been effected by this method instead of assuming unproven equivalence of both configurations. Also, in reviewer's opinion, a very useful reference dealing with the problem of this nature is the work by Avrami and Little [Avrami, L., and Little, J. B., *J. appl. Phys.* **13,** p. 255, 1942] who gave a very general derivation of the temperature distribution in a fin of rectangular cross section. The fact that author limits his discussion only to rectangular cross section of the rib and assumes somewhat unrealistic boundary conditions on the liquid cooling side renders his technique useful in a limited number of cases.

B. Zarwyn, USA

4178. Bloxsom, D. E., Jr., Cooling of solid surfaces with heat power inputs over 10^5 watts/cm^2, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 159–172.

For an energy input to a surface of 10^5 watts/cm^2, or 8.9×10^5 BTU/ft^2 sec, the only mechanism of cooling that requires consideration is vaporization of the material. Cooling by conduction is negligible for this rate of heating. Three occurrences of rates of heat input of this magnitude are: the electrodes of arcs, the throats of wind tunnels, and parts of the surface of very high speed aircraft.

From the equation for heat balance at the wall, the volumetric heat of vaporization in joules/cm^3 was predicted to define the rate of loss of material. Experiment confirms the prediction for carbon, carbides, and molybdenum provided they are protected from mechanical forces and thermal shock. Experiment also shows that the heat of oxidation does not contribute to the rate of erosion. For materials that soften, or melt below 2500K, the materials are often blown away in drops. F. Todd, USA

4179. Sigalla, A., The cooling of hot steel strip with water jets, *J. Iron Steel Inst. Lond.* **186,** part 1, 90–93, May 1957.

Two series of experiments have been undertaken on the cooling of hot steel strip, and their relevance to the design of strip cooling systems is discussed. It has been found that rapid cooling can be achieved using simple water jets, and a formula is given from which the approximate number required can be calculated.

From author's summary

4180. Kwong, S. S., and Smith, J. M., Radial heat transfer in packed beds, *Indust. Engng. Chem.* **49,** 5, 894–903, May 1957.

4181. Fay, J. A., Riddell, F. R., and Kemp, N. H., Stagnation point heat transfer in dissociated air flow, *Jet Propulsion* **27,** 6, 672–674, June 1957.

Authors present the solutions of appropriate differential equations obtained on an IBM 650 computer. Fluid properties were taken from NBS tables for the equilibrium case. For the nonequilibrium boundary-layer cases, the average air properties were determined by the relative concentration of oxygen and nitrogen in the equilibrium state behind the normal shock, but outside the boundary layer. The nonequilibrium states considered were the frozen boundary layer with catalytic and noncatalytic walls, and the finite-recombination-rate case. Transport properties and recombination rates were estimated. The Lewis and Prandtl numbers were found to be practically independent of temperature, and were assumed constant throughout the boundary layer.

The results take the same form as the equation of Subulkin which was obtained by extrapolating the results of low-speed flow to supersonic flow. The authors' equations for the equilibrium and frozen boundary layer differ only in the exponent of the Lewis number. For a Lewis number greater than one, the frozen-state heat-transfer rate is only slightly increased, but for a Lewis number less than one, the heat-transfer rate may be decreased to one half the equilibrium state heat-transfer rate.

T. L. Eckrich, USA

4182. Meiners, K., Heat transfer from a horizontal shaft heated in one end (in German), *ZVDI* **99,** 15, 667–671, May 1957.

Report covers heat-transfer data on several shafts (58, 29, and 15 mm) running with speeds from 0 to 3000 rpm and surface temperatures up to 100 C. The results are presented in a graph with average Nusselt number against Reynolds number in the region $300 < Re < 30{,}000$. A comparison with the works of Etenard and Anderson & Saunders is likewise shown. Details of boundary-layer behavior are also included.

It is an interesting report which should not be too difficult to understand with a limited knowledge of German.

M. Rand, Canada

4183. Glawe, G. E., and Johnson, R. C., Experimental study of heat transfer to small cylinders in a subsonic, high-temperature gas stream, *NACA TN* 3934, 21 pp., May 1957.

A Nusselt-Reynolds number relation for cylindrical thermocouple wires in crossflow was obtained from the experimental determination of time constants. Tests were conducted in exhaust gas over a temperature range of 2000 to 3400 R, a Mach number range of 0.3 to 0.8, and a static-pressure range from 2/3 to 1-1/3 atmospheres. Combinations of these conditions yielded a Reynolds number range of 450 to 3000, based on wire diameter.

From these data, the correlation obtained between Nusselt and Reynolds numbers with average deviations of a single observation of 8.5% is

$$Nu = (0.428 \pm 0.003)\sqrt{Re^*}$$

where Re^* is the Reynolds number based on evaluation of gas density and viscosity at total temperature, and Nu is the Nusselt number with gas thermal conductivity computed at total temperature. This correlation equation agrees with the one previously reported in *NACA TN* 2599 for room-temperature conditions.

From authors' summary by D. Bendersky, USA

4184. Marris, A. W., Steady state heat transfer to fully developed turbulent flow in a curved channel, *Canad. J. Phys.* **35,** 4, 410–434, Apr. 1957.

Paper develops a vorticity transfer analogy theory for the turbulent heat transfer in a fully developed flow between concentric rotating cylinders with assumed two-dimensional mean motion. The results are similar to those of Howarth for the flate plate: the theory, by a suitable choice of constants, agrees with the measured velocity and temperature distributions except in regions adjacent to the solid boundaries.

Since the author states that principal justification of the work is to yield engineering results, inclusion of the usual Nusselt-Reynolds plot with comparison of experimental data would have been a valuable addition to the paper. W. Daskin, USA

4185. Hardy, J. K., and Brown, C. D., Kinetic temperature of propeller blades in conditions of icing, *Aero. Res. Counc. Lond. Rep. Mem.* 2806, 12 pp., 1954.

The kinetic temperature of a section of a propeller blade has been calculated for a blade with high thermal conductivity, and also for a blade which is nonconducting. Calculations have been made for clear air and for conditions of icing to find the extent to which kinetic heating is effective against ice. On a nonconducting blade the temperature is lowest at the position, on the cambered face, where the velocity of the air is greatest. At this position there is practically no protection from kinetic heating. In the case of a blade which is a good conductor, the average temperature is calculated by balancing the flow of heat by convection to and from the blade. The average temperature is substantially above the minimum temperature on a nonconducting blade. The average temperature has been calculated for a range both of conditions of icing and of operation. From author's summary

4186. Tsubouchi, T., Sato, S., and Usami, H., On the heat transfer coefficients of cylindrical bodies, *Sci. Rep. Res. Inst. Tohoku Univ. Japan* (B) **7,** 63, 31–44, 1956.

In this investigation, the heat losses from the end surfaces of a circular cylinder, which are located horizontally upward and downward in the still air, have been measured by "the temperature boundary-layer method" together with the usual "heat quantity method," both where the cylindrical surface is heated and where it is not. From the experimental results, the local and the mean heat-transfer coefficients of each surface are evaluated and expressed by the experimental formulas, which show remarkable differences from the case of horizontal plates.

From authors' summary

4187. Novikov, I. I., Solovyev, A. N., Khabakhpasheva, E. M., Gruzdev, V. A., Pridantsev, A. I., and Vasenina, M. Ya., Heat transfer and thermophysical properties of molten alkali metals, *Soviet J. Atomic Energy* no. 4, 545–560, 1956.

An investigation was undertaken of heat transfer to molten sodium during turbulent flow in a round copper or nickel tube. An interpolation formula was obtained. Experiments were conducted to determine thermal resistance between liquid sodium and a solid wall of copper, nickel, and stainless steel. Methods were developed for measurement of viscosity, temperature conductivity and density of molten metals. Results are given for measurements of these physical parameters for molten alkali metals (sodium, potassium, lithium and the eutectic solution of sodium and potassium) in a broad interval of temperatures.

From authors' summary by W. Green, USA

4188. Trefethen, L., Measurement of mean fluid temperatures, *Trans. ASME* **78,** 6, 1207–1212, Aug. 1956.

Analysis is made of differences between methods of measuring mean fluid temperatures and the effect of these differences on Nusselt numbers. Heater input and mixing box temperatures are shown to be identical, but the energy and probe mean temperatures vary due to axial heat conduction. Attempt to explain discrepancy of liquid metal data and theory was not successful.

Discussion of paper clarified some points and should be read.

A. C. Mueller, USA

4189. Fawcett, S. L., and Grimble, R. E., Use of the cyclic heat-temperature variation method for measurement of reactor heat-transfer coefficients, *Chem. Engng. Progr.* **50,** Symp. Series no. 11 (Nuclear Engng. Pt. I), 135–137, 1954.

4190. Ostrach, S., Convection phenomena in fluids heated from below, *Trans. ASME* **79,** 2, 299–305, Feb. 1957.

Author reviews previous research on subject, particularly in relation to fluids between two isothermal horizontal plates or two vertical plates with linear temperature gradient along the plates. Equilibrium, columnar, cellular (Bénard), and turbulent flow regimes are discussed for completely natural convection and spindle-like, modified cellular, and roll-like regimes for superposed steady flow.

A. E. Bryson, Jr., USA

4191. Chandrasekhar, S., The instability of a layer of fluid heated below and subject to the simultaneous action of a magnetic field and rotation, *Proc. roy. Soc. Lond.* (*A*) **237,** 1211, 476–484, Nov. 1956.

The theory described in an earlier paper [Chandrasekhar 1954] is extended to include the possibility that a layer of fluid heated below and subject to the simultaneous action of a magnetic field and rotation can become unstable via a marginal state of purely oscillatory motions. It is shown that depending on the value of the nondimensional parameters Q and T and the coefficients of kinematic viscosity and thermal and electrical conductivities, instability can set in either as convection or as overstability. Numerical results are derived for the case when the physical constants are those applicable to mercury at ordinary room temperatures. The nature of the effects one may expect to observe are illustrated.

From author's summary

4192. Mathers, W. G., Madden, A. J., Jr., and Piret, E. L., Simultaneous heat and mass transfer in free convection, *Indust. Engng. Chem.* **49,** 6, 961–968, June 1957.

In this study authors consider a volatile or soluble object, located in a fluid that is unsaturated with the material of the object. There will be a transfer of the material to the fluid, and at steady state this will result in a changing composition as one moves out from the surface of the object into the bulk of the fluid; if, at the same time, the surface temperature is different from that of the bulk of the fluid, there will also exist point-to-point changes in temperature. The density of a fluid element will be determined by its composition and its temperature, so that in the neighborhood of the object the fluid density will differ from that in the bulk of the fluid. This density difference will create a buoyant force on the fluid within the boundary layer, which will cause it to move at such velocity that at every point within the boundary layer the buoyant force of a fluid element is balanced by the viscous drag and acceleration of the element. The resulting flow of the fluid near the object causes heat and mass to be transferred at a higher rate than if no convection currents were present.

This problem is considered first for a vertical plate of material situated in a quiet incompressible fluid, infinite in extent, the plate being maintained at a temperature different from that of the fluid. The differential equations of balance of force, of total material, of heat, and of volatile material component are set up. These can be solved either analytically, or numerically by means of an analog computer. The numerical results are compared with those of previous workers. Also the case of spheres in gases is considered, and an experimental set up for it is described. The results are applicable to vaporization of spray droplets, and to the performance of packed catalytic reactors.

K. J. DeJuhasz, Germany

4193. Van Itterbeek, A., and Nihoul, J., Measurements of thermal diffusion in H_2-He mixtures by using ultrasonics, *Acustica* **5,** 2, 142–145, 1955.

An ultrasonic interferometer has been used to measure the change of the concentration produced by thermal diffusion in H_2-He mixtures. With this method the separation degree has been measured as a function of the concentration and the temperature. From these measurements the thermal diffusion factor α was calculated; thus $\alpha = 0.149$ was obtained. The change of the concentration was measured as a function of time in H_2-N_2 mixtures by means of the velocity. Good agreement was obtained with Clark Jones and Furry's theory [*Rev. mod. Phys.* **18,** p. 151, 1946].

From authors' summary

4194. Jenne, O., Design of regenerators (in German), *Radex Rundschau* no. 5, 494–498, 1955.

In a few model laws the dependence of certain dimensions and operating conditions upon the size of the complete unit is shown, and is represented for the three most commonly used regenerators by graphs which are easy to read. The computations made in connection with the preparation of these graphs also make possible the dimensioning of hot blast stoves, open-hearth chambers and Ljungstroem preheaters for boiler plants, as well as the establishment of the essential operating conditions without time-consuming calculations.

From author's summary

4195. Polozhiy, S. V., The boiling of a liquid by heat transfer through a wall (in Russian), *Izv. Tomsk. politekh. in-ta* **80,** 24–40, 1955; *Ref. Zh. Mekh.* 1956. Rev. 4536.

The fundamental relationship between the surface tension σ, radius of curvature of the steam bubble ρ, and excess boiling temperature of the liquid Δt_σ above the tabular saturation temperature has the form

$$\Delta t = \frac{2\sigma}{\rho}\frac{\Delta T_s}{r\gamma''} = \frac{B}{\rho}$$

The conclusion is reached that the process of steam generation at constant external pressure and saturation temperature above the plane phase interface proceeds in fact under variable-temperature conditions produced by the phenomena at the liquid surface. In this regard, two regions of boiling are observed: a high-intensity region in which the vapor phase (steam) originates, and the bubbles grow rapidly, in which the capillary pressure falls rapidly with a corresponding drop in the steam temperature in and around the bubble; and a low-intensity region in which the process of steam generation is completed, and which is characterized by slow growth of the bubbles and a slow change in the temperature of the steam in the bubble as well as in the surrounding liquid phase.

Existing definitions of the temperature development and process of boiling are critically examined and a more accurate formulation is suggested: boiling being defined as the process in which the steam is formed, not only on the surface, but also within the liquid phase; the boiling point of any liquid being defined as that temperature at which the saturation vapor pressure is the same as the pressure over the liquid phase plus the internal pressure.

The results of observations on the process of steam generation at pressures below atmospheric are communicated, and explanations are furnished, from the author's conclusions, of the terms "film boiling," and "bubble boiling."

The particular characteristics are examined of the boiling of a liquid under high surface tension as well as on a nonwettable surface. The analytical criteria of G. N. Kruzhilin [*Izv. Akad. Nauk SSSR Otd. tekh. Nauk* 1948 (7)] are examined and the erroneous character of the extensively used Fritz formula [W. Fritz, *Phys. Z.* 1935 (11)] for determining the breakaway diameter of the bubbles at other than atmospheric pressure is pointed out.

Courtesy Referativnyi Zhurnal P. I. Povarnin, USSR
Translation, courtesy Ministry of Supply, England

4196. Hu, P. M., and Parsons, R. W., A thermostat using a resistance thermometer and a galvanometer-photocell amplifier, *J. sci. Instrum.* **34,** 7, 283–285, July 1957.

4197. Taylor, C. L., Description and prediction of human response to aircraft thermal environments, *Trans. ASME* **79,** 5, 1024–1028, July 1957.

Combustion

(See also Revs. 3887, 4054, 4069, 4138, 4177, 4215)

4198. Palmer, K. N., and Tonkin, P. S., The ignition of dust layers on a hot surface, *Combustion and Flame* **1,** 1, 14–18, Mar. 1957.

Authors measured dust ignition temperatures on hot surfaces as functions of temperature, dust thickness, and particle size. Some precarbonized dusts are included, along with natural cork, wood, and coal dusts. Increasing dust thickness and decreasing particle size tend to lower ignition temperature. Extrapolations yield 155 C and 210 C as minimum ignition temperatures in air for coal and wood dusts, respectively. Application to practical fire prevention problems is considered. J. S. Arnold, USA

4199. Goodger, E. M., The influence of engine speed upon preignition, *Coll. Aero. Cranfield Rep.* 51, 8 pp. + 1 table + 12 figs., Sept. 1956.

The literature shows conflicting evidence on the effect of engine speed upon tendency to preignition. Typical published results are presented and compared, together with results obtained from a single-cylinder D. V. L. engine at Cranfield, using the heated-wire and ionization-gap technique.

The D.V.L. results show an initial increase in preignition tendency with increase in engine speed, followed by a reduced tendency with further increase in speed, and are thus similar to certain other published results. The D.V.L. results are less detailed than these published results, since no measurement was made of hot-spot temperatures, but are more extensive, since a greater number of fuels was tested for speed effect, and preignition tendency with speed was measured over a range of (reduced) inlet pressure.

From author's summary

4200. Kurz, P. F., Influence of diborane on blow-off limits of hydrocarbon flames, *Combustion and Flame* **1,** 2, 212–216, June 1957.

Since earlier work on effects on flame speeds of addition of diborane to propane indicated that propane might be inhibiting the more rapid combustion reactions of diborane, further experiments have been made to determine the effect of added diborane on the stability limits of hydrocarbon flames. Tests were made on propane and isobutane flames.

Argon was used to increase flow velocities, so dilution occurred as the flow velocity increased in observing blow-off. The effect of diborane was found to be different from that of adding a second hydrocarbon. This is attributed to selective burning of the fast-reacting diborane. R. C. Anderson, USA

4201. Kurz, P. F., Some factors influencing stability limits of Bunsen flames, *Combustion and Flame* **1,** 2, 162–178, June 1957.

This is a continuation of studies on burner stability reported earlier. The factors included in the present report are variations in burner diameter and the influence of different shielding gases, such as nitrogen and helium, as compared to air.

The critical velocity gradient for blow-off was not affected by burner diameter.

Helium in an annular stream shielding the flame narrows both lean and rich blow-off limits, but neither nitrogen nor helium affect flashback. The effect of nitrogen is similar to that of a Smithells tube.

These effects may be explained on a thermal basis in terms of the relative ease of entrainment of the shielding gas in the fuel-air stream of the burner. Similarities in effects of nitrogen and air on lean blow-off confirm the idea that under such conditions excess air behaves as a diluent. R. C. Anderson, USA

4202. Matton, G., Flame stabilization by baffles: Aerodynamic study of the wake (in French), *Rech. aêro.* no. 57, 11–17, Mar.–Apr. 1957.

The equations used to correlate experimental data on limits of flame blow-off from baffles generally lead to considerable spread, due to a lack of knowledge of the width of the stabilizing recirculation zone and the velocity along the streamlines bordering this zone.

It appears that the aerodynamic configuration of the wake in the presence of a flame is similar to that without a flame behind the same baffle with an axial vane added downstream. Thus measurement, in the presence of flame, of the pressure right behind the baffle makes it possible to relate the velocity V' along the streamlines to the approach velocity, and the width d' of the wake to that of the baffle.

With these new data a very narrow spread is obtained for the experimental blow-off limits on a variety of two-dimensional baffles from a single curve for V'/d' as a function of air-fuel ratio.

From author's summary by A. G. Cattaneo, USA

4203. Simmons, R. F., and Wolfhard, H. G., Some limiting oxygen concentrations for diffusion flames in air diluted with nitrogen, *Combustion and Flame* **1,** 2, 155–161, June 1957.

Measurements have been made of the limiting oxygen concentrations ($O_2/O_2 + N_2$) at which diffusion flames burn in air diluted with nitrogen. These were determined for comparison with the data of Coward and Jones on premixed flames.

A porous stainless-steel hemispherical burner was used. This avoids cooling by the burner itself, such as occurs with cylindrical burners, and makes possible determinations with liquid fuels as well as gaseous.

The results are useful for determining flame propagation limits of fuels for use in assessing fire hazards, but they do not, of course, measure the ease of ignition.

Limiting oxygen indices were determined for fuels of a variety of structural types. In general the values agree with those for stoichiometric premixed flames. It is concluded that the value is determined by the limiting flame temperature and represents the dilution at which the flame temperature becomes reduced to its limiting value so that the flame is extinguished.

R. C. Anderson, USA

4204. Fristrom, R. M., and Westenberg, A. A., Flame zone studies. IV—Microstructure and material transport in a laminar propane–air flame front, *Combustion and Flame* **1,** 2, 217–228, June 1957.

Article constitutes part of the reports of extensive flame-front studies and ties in closely with the previously published work of R. M. Fristrom and associates.

Omitting the experimental techniques description (discussed in a former article) and using data also described elsewhere (mass average gas velocity normal to the flame front, stream-tube cross-sectional area parallel to the flame front, as dimensionless ratios relative to initial cold gas values), authors present detailed experimental information on laminar, initially stoichiometric propane-air mixture at 1¼ atmos.

Eleven graphs of "concentrations and fractional mass rates of flow of stable species as function of distance from center of luminous zone" are given. Atoms and radicals are included in the measured stable components.

Report on atom balance check is included. Reproducibility of observed stable components is reported as good except for hydrogen and carbon monoxide.

Chemical kinetic aspects are not discussed.

I. A. Black, USA

4205. Egerton, A. C., Minkoff, G. J., and Salooja, K. C., The slow oxidation of methane—the role of the surface on the course of the oxidation of methane, *Combustion and Flame* **1,** 1, 25–51, Mar. 1957.

The slow oxidation of methane has been studied at temperatures from 450 to 500C and pressures from 100 to 400 mm Hg. Amounts of formaldehyde and hydrogen peroxide have been determined. The effect of different glasses and coatings has been studied with respect to activation energy and reaction rate. The effects of diluents such as nitrogen, argon, and helium were also investigated. The results are discussed in relation to work on methane oxidation by Norrish, Hoare and Walsh, and others. It is concluded that other intermediates beside formaldehyde control the rate and that, as in the hydrogen-oxygen reaction, the radical HO_2 plays an important part.

From authors' summary by R. Delbourgo, France

4206. Hall, A. R., McCoubrey, J. C., and Wolfhard, H. G., Some properties of formaldehyde flames, *Combustion and Flame* **1,** 1, 53–59, Mar. 1957.

Some properties of formaldehyde with oxygen and nitric oxide, notably the spectra and the oxygen index, are reviewed and compared with those of its main thermal decomposition products, i.e., carbon monoxide and hydrogen, on the one hand, and of organic bodies on the other. Some deductions are made about the combustion mechanisms with the formaldehyde flames. The usefulness of spectral data obtained with flames of a relatively simple compound, such as formaldehyde, in helping to understand the combustion of more complex compounds is illustrated for flames of ethyl nitrate and methyl nitrite with oxygen.

From authors' summary by R. Delbourgo, France

Acoustics

(See also Revs. 3917, 4193)

4207. Maidanik, G., Acoustical radiation pressure due to incident plane progressive waves on spherical objects, *J. acoust. Soc. Amer.* **29,** 6, 738–742, June 1957.

Radiation pressure exerted by a plane wave incident on a sphere is computed by means of a convenient general expression derived by Westervelt [title source **29,** p. 26, 1957]. Numerical results are presented for "hard," i.e., incompressible, and "soft," i.e., pressure releasing spherical scatterers.

M. C. Junger, USA

4208. Smith, P. W., Jr., Sound transmission through thin cylindrical shells, *J. acoust. Soc. Amer.* **29,** 6, 721–729, June 1957.

The sound insulation provided by cylindrical shells is a basic consideration in the design of aircraft fuselages, one of whose functions is to protect the passengers from the sound generated by ever more powerful and noisier engines. The paper under review presents an analysis of the interaction of a plane wave and an elastic cylindrical shell. The insulating properties of the shell are presented in the form of extensive graphs of constant reactance contours versus frequency. The shell is assumed of infinite length. The orientation of the wave with respect to the cylindrical axis is arbitrary. As in the case of plane panels, it is found that for a given frequency, the shell provides very little insulation for certain critical angles of incidence. Different modes present absorption peaks of varying sharpness.

M. C. Junger, USA

4209. Waterhouse, R. V., Interference patterns in reverberant sound fields, *J. acoust. Soc. Amer.* **27,** 2, 247–258, Mar. 1955.

Reverberant sound fields depart considerably from a diffuse sound field, characterised by the properties: (1) Uniform distribution of sound energy; (2) equal mean energy flow in all directions and in all points; (3) random phase relations. In reverberant sound fields, the energy is not uniformly distributed, but is distributed into interference patterns at the boundaries and at any reflecting surface large compared to the wave length of the sound. This arises from the fact that the phases of the wave trains near reflecting surfaces are not entirely random, owing to the reflection of these surfaces. The energy density is not the same in all points of the field, but is greater near the wall, where it rises to a value 2.2 db higher than its asymptotic value. If there are two reflectors at right angles, or three reflectors in a corner, the energy density will rise still more in their neighborhood.

The interference pattern originating from integration over a band of one octave has the same form as the pattern of a single frequency wave; even a band of 5 octaves shows the same particularities. Some experimental confirmations of the mentioned phenomenon are indicated, such as its influence on the place of the microphone for performing acoustical measurements.

W. H. Muller, Holland

4210. Blokhintsev, D. I., Excitation of resonance by air flow, *David W. Taylor Mod. Basin Transl.* 270, 11 pp., Jan. 1957.

Closed tube (square section) resonators were placed in wind tunnel supplying airflow up to 30 m/sec. Results confirm qualitative supposition that phenomenon involves interaction between vortices shed at resonator edge and natural oscillations of resonator. Excitation occurred (at velocities up to 30 m/sec) for angle between flow and resonator axis between 45° and 85°. Resonant sound pressure was proportional to velocity head of flow, with proportionality constant between ⅓ and ⅙. Theoretical sound pressures agree within 3 db of those observed. Resonance can be reduced by absorbent in resonator, or by fine screen placed just upwind of mouth.

V. Salmon, USA

4211. Phillips, O. M., The intensity of Aeolian tones, *J. fluid Mech.* **1,** 6, 607–624, Dec. 1956.

Paper is an application of the general theory of aerodynamic sound to the classical problem of flow past a rigid circular cylinder. Sound is generated principally by a line of dipoles, representing the fluctuating transverse lift force, which the author calculates from the experimental data of Kovasznay [AMR **3,** Rev. 2444]. Method requires knowledge of phase fluctuations at different points along the cylinder; accordingly, author determines the axial length scale by auxiliary experiments. Formula for the mean-square acoustic pressure is derived, indicating a dependence on the sixth power of the velocity. Good agreement is obtained with experiments carried out in the National Physical Laboratory at Reynolds numbers of order 100.

Author briefly discusses flow with a turbulent wake. This causes a reduction in the axial length scale, because of the

random nature of turbulence. Hence the numerical factor in the formula for mean-square sound pressure is reduced. This is borne out experimentally. N. Curle, England

4212. Solnick, R. L., and Bishop, R. H., Noise, vibration, and measurement problems, resulting from fluid-flow disturbances, *Trans. ASME* **79,** 5, 1043–1056, July 1957.

This paper has been prepared to give the reader a general understanding of the noise, vibration, and measurement problems resulting from fluid-flow disturbances. The occurrence of these problems in power plants has been given particular attention.

From authors' summary

4213. Erdelyi, E., and Horvay, G., Vibration modes of stators of induction motors, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–28, 7 pp.

The increased emphasis placed on the design of "noiseless" machinery has led to the requirements of better evaluation of the magnetic attractive forces developed between rotor and stator of induction motors, better evaluation of stator response to such forces, and better evaluation of the sound waves radiated by the vibrating stator frame. This paper treats the crucial phase of the problem, determining the vibration characteristics of two concentric shells (stator core inside the stator frame) coupled by nonrigid ribs. The vibration theory of such coupled structures is developed and the theoretical results are compared with the experimental measurements obtained for a 30-hp, 3-phase, induction motor. The agreement is within 7%. Parts 1 and 3 of the problem, determination of the airgap force waves and of the sound radiated, are discussed in separate papers.

From authors' summary

Ballistics, Detonics (Explosions)

(See also Rev. 4130)

4214. Idatte, M. P., Efficiency of anti-aircraft shooting (in French), *Mém. Artill. fr.* **30,** 118, 835–939, 1956.

Author gives a very detailed study of anti-aircraft firing with classical guns and projectiles. He states that the classical methods and materiel are still of great interest because of their flexibility, although guidance with homing heads and teleguidance are used more and more in anti-aircraft defense. Giving a detailed analysis of the volume of attainment and dispersion for all types of projectiles: classical with proximity, MTSQ and SQ fuzes, and guided missiles, author concludes that in actual area of anti-aircraft defense, efficiency of classical projectiles can be compared with efficiency of guided missiles at heights between 200 and 4000 m. In certain cases this height can be extended up to 6000 m. Of course, classical projectiles must have proximity fuzes. At heights over 6000 m, efficiency of classical artillery becomes inadequate and projectile of new design or guided missiles must be applied. The caliber of the classical guns cannot be greater than 90 mm, with muzzle velocity about 850 m/sec. Firing in a larger caliber would be very complex, very expensive, and without efficiency of a guided missile. J. Marinkovic, Yugoslavia

4215. Nicholls, J. A., Wilkinson, H. R., and Morrison, R. B., Intermittent detonation as a thrust-producing mechanism, *Jet Propulsion* **27,** 5, 534–541, May 1957.

Authors show by a simplified theory that a reaction device operating on intermittent detonation gives, in general, high specific thrust and low specific impulse, but it gives high specific impulse and low specific thrust in the case of hydrogen-air mixture. Impulse derived from a single detonation wave is measured by suspending a detonation tube as a pendulum. Results for hydrogen-oxygen mixture show good agreement with theory for volumetric-mixture ratio larger than 40%. Experiments on acetylene-oxygen show only fair agreement with theory. Tests on intermittent detonation of hydrogen-air are carried out by using a cyclic detonation tube mounted on a cantilever beam. Thrusts and temperatures are measured for various frequencies, fuel-air ratios, and air-flow rates. Specific impulse of over 2100 sec is obtained as predicted by the theory. F. Tamaki, Japan

4216. Leitmann, G., Optimum thrust programing for high-altitude rockets, *Aero. Engng. Rev.* **16,** 6, 63–66, June 1957.

The paper discusses the problem of establishing the thrust-time relation which will achieve the optimum compromise between reduction in gravity and drag losses and thereby result in minimum fuel expenditure. From author's summary

4217. Liu, V.-C., On the motion of a projectile in the atmosphere, *ZAMP* **8,** 1, 76–82, Jan. 1957.

The equation of rectilinear motion of a projectile which moves in an atmosphere, of which the density decreases exponentially with the altitude, is solved. It is found that the velocity of the projectile can be expressed explicitly in terms of confluent hypergeometric functions. This theory is applied to treat two specific problems: (1) the flight analysis of a sounding rocket during the free-flight period and (2) the calculation of ambient temperature from the trajectory of a spherical projectile.

From author's summary

4218. Sundin, Elis, Calculation of projectile trajectories with emphasis on air defense (in Swedish), *Artill. Tidsk.* **85,** 5, 142–147, 1956.

Author proposes simple analytic expressions which are usable in anti-aircraft computers. As mathematical model of projectile motion author uses linear differential equations with constant coefficients. Solution accuracy in time of flight and angle of departure is good under special conditions; for example, standard atmosphere.

Approximations of physical rules mean, in reviewer's opinion, that coefficients must vary smoothly with differences from standard conditions if method is to be suitable in practice.

A. Silfverhielm, Sweden

4219. Bussard, R. W., A nuclear-electric propulsion system, *J. Brit. interplanetary Soc.* **15,** 6, 297–304, Nov.-Dec. 1956.

Soil Mechanics, Seepage

(See also Rev. 3934, 4021, 4223, 4224, 4225, 4226)

4220. Gilg, B., and Gavard, M., Calculation of the permeability of soils from well-point data (in French), *Bull. tech. Suisse Rom.* **83,** 4, 45–50, Feb. 1957.

Nomograms and simple formulas are developed from which soil permeability may be found by using results of both constant and falling head field tests. R. E. Gibson, England

4221. Vey, E., Frictional resistance of steel H-piling in clay, *Proc. Amer. Soc. civ. Engrs.* **83,** SM 1 (*J. Soil Mech. Found. Div.*), Pap. 1160, 31 pp., Jan. 1957.

Large-scale field tests were conducted on steel H-piling driven through medium clay to end bearing in very hard soil. One of the piles, a 10CBP42, was instrumented at intervals throughout its length with electric resistance strain gages. The pile was loaded in increments according to a prescribed load-testing procedure and then unloaded in decrements. A second loading cycle was carried out in the same manner except that it was continued until the pile failed.

Two soil borings were made; one at the center of the pile group before any piles were driven and the second directly adjacent to a pile, after all piles had been driven and tested. Laboratory tests were made on soil samples from both borings. The results indicated (1) that very little disturbance of the clay resulted from pile driving and testing and (2) that the shear resistance of the clay as measured in the laboratory by unconfined compression was in reasonably good agreement with values obtained from strain-gage measurements in the field. From author's summary

Micromeritics

(See also Revs. 4074, 4075).

4222. Woods, L. C., On harmonic functions satisfying a mixed boundary condition with an application to the flow past a porous wall, *Appl. sci. Res. (A)* **6,** 5/6, 351-364, 1957.

Author considers the determination of the flow field for incompressible, nonviscous, two-dimensional flow of a fluid past a porous surface. It is assumed that the pressure loss coefficient for flow through the surface is known from experiment. For the specific case considered in the paper, the velocity normal to the surface is taken to be small (linearized flow) and to vary as the first power of the pressure drop across the wall. In this instance it is shown that the solution involves the determination of an analytic function subject to the condition at the boundary that its real and imaginary parts are related in a linear way. This problem is treated in general by reducing it to two simultaneous Dirichlet problems. The method is applied to examples of flow past an infinite wall, with porosity a function of length, and flow past an airfoil in a slotted wind tunnel. R. Siegel, USA

4223. Rabinovich, B. I., Equations for the perturbed motion of a solid with a cylindrical cavity partially filled with a liquid (in Russian), *Prikl. Mat. Mekh.* **20,** 1, 39-50, Jan./Feb. 1956.

The equation for the perturbed motion of a solid with cylindrical cavity, inclined slightly from the direction of gravity, is discussed and is simplified by taking a special point as the origin. No example is given. M. Kataoka, Japan

4224. Abbaov, M. T., and Mirzajanzade, A. Kh., Application of the dynamic similarity method in subterranean hydrodynamics (in Russian), *Neft. kh-vo* no. 7, 47-51, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4593.

Similarity considerations are discussed in application to the different problems of the hydrodynamics of underground flows (filtration of a viscous, incompressible fluid in an unvarying porous medium, unsteady filtration of a compressible fluid, filtration of a compressible fluid in an elastic porous medium). The appearance of a square-law resistance in filtration problems is explained by the authors by analogy with the existence of a similar square law of resistance in pipe flows. This is inadmissible. The square-law resistance of a fluid flow in a straight pipe is associated with the appearance of developed turbulence; flow through pores, on the other hand, in the overwhelming majority of cases, is laminar, and the transition from a linear to a square law of resistance is explained by the increasing influence of inertia forces (the pores are heavily curved). Furthermore, it is impossible to agree with the authors' statement that in the motion of a compressible fluid a material part is played by the Mach number (ratio of flow velocity to velocity of sound). In filtration problems, this number is always negligibly small, while in the presence of substantial compressibility of the liquid the material factor is quite another similarity constant, linking a particular mean speed of sound for the liquid/porous medium system with the dimensions of the region of perturbed motion and certain other determining parameters.

Courtesy Referativnyi Zhurnal G. I. Barenblatt, USSR
Translation, courtesy Ministry of Supply, England

4225. Charny, I. A., The limiting discharges and depressions in water-borne and subgaseous petroleum deposits (in Russian), Conference on the development of scientific researches in the field of secondary methods of petroleum winning; Baku, Akad. Nauk AzSSR, 1953, 81-109; *Ref. Zh. Mekh.* 1956, Rev. 3754.

Author examines the potential flow in a homogeneous stratum tapped by an incomplete borehole containing two immiscible superposed liquid bodies of differing volume density. The flow is axially symmetrical. One of the liquids flows into the borehole, the other remains stationary, forming a "cone." It is assumed that the liquids are divided by a pronounced interfacial plane.

The solution is founded on a scheme suggested by Muskat, in which it is assumed that in the particular flow the potential distribution approximately coincides with the potential distribution of a single inflowing liquid occupying the whole stratum.

To determine the ordinate of the point of greatest displacement of the dividing interface with regard to its position on the contour, the graphical solution proposed by Muskat is replaced by analytical expressions enabling determination of the apex of the cone in relation to the sink or discharge. The corresponding delivery can be determined from the position of the apex of the cone thus determined.

Paper describes a method for calculating the limiting depression which is founded on utilizing data furnished by electrolytic analogs of the incomplete boreholes, and a method for evaluating the filtration resistance of incomplete boreholes analytically. The deviations from the linear law existing in the vicinity of the perforating openings are approximated. In the nonlinear region, a binomial resistance law is applied. The concluding section examines the case of an inflow to a system of boreholes tapping a stratum with a subjacent water table. Around the boreholes circular regions are plotted, outside which the flow is regarded as two-dimensional. Within these plotted areas the solution is found in the manner described. The areas are conjoined on the condition of equality of pressure and volume of flow at the boundary.

In conclusion, from the same postulates author analyzes the delivery of horizontal bores tapping a stratum with a subjacent water table.

Subsequently [*Ref. Zh. Mekh.* 1954, Rev. 2208], author obtained more accurate relationships, enabling estimation of the possible water and gas-free deliveries. The method described in the paper under discussion gives delivery values closely approaching the upper limit of the possible deliveries.

Courtesy Referativnyi Zhurnal D. A. Efros, USSR
Translation, courtesy Ministry of Supply, England

4226. Rain, evaporation, filtration and draining, Proc. Third Symposium on Hydraulics, Alger, April 14, 1954; France, La Houille Blanche. 316 pp.

Geophysics, Meteorology, Oceanography

(See also Revs. 3891, 3925, 4008, 4110)

4227. Favre, B., Determination of the coefficients of the linear velocity laws as a function of the depth of seismic reflection (in French), *Rev. Inst. fr. Petrole et Ann. Comb. liq.* **11,** 7/8, 863-868, July/Aug. 1956.

4228. Bowden, K. F., Physics in oceanography, *Brit. J. appl. Phys.* **7,** 8, 273-281, Aug. 1956.

The physics of the oceans is a subject in which considerable progress has been made in recent years, largely because of the increasing application of new techniques. Some examples of the development or adaptation of physical methods for research at sea are described, with some of the results they have given in problems such as those of waves, storm surges, and ocean currents. From author's summary

4229. Neumann, G., Wind stress on water surfaces, *Bull. Amer. Meteor. Soc.* **37,** 5, 211–217, May 1956.

Various attempts to estimate the total wind stress at the sea surface are briefly reviewed, and the difficulties in the application of the methods used in the past are discussed.

The results obtained under natural conditions, that is over larger bodies of water such as the open sea or large lakes, agree fairly well with each other, whereas great discrepancies are observed with wind-tunnel experiments. It is conceivable that the stress values obtained from wind-tunnel experiments only hold for the special conditions encountered with small-scale flow models. The most important hydrodynamical differences in the flow at both sides of the air-sea interfaces between small-scale models and large-scale natural bodies of water are pointed out.

From author's summary

4230. Lineikin, P. S., Theory of the effect of unsteady wind currents on deep seas (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **106,** 1, 47–50, Jan. 1956.

Author continues a preceding investigation [*Dokladi Akad. Nauk SSSR,* **101,** 3, 1955] which refers to the behavior of the water surface in a deep channel with vertical parallel walls under the action of wind. The velocity components of the wind field are assumed to be developed in Fourier series dependent on x (coordinate in the direction of the channel). The velocity components and the disturbance of the density field are expressed by nine auxiliary functions given in integral form, five of which refer to the gradient flow, whereas the other four represent the drift flow.

W. Wuest, Germany

4231. Mkhitarian, A. M., Influence of vertical turbulent mixing on the pressure distribution at sea level (in Russian), *Dokladi Akad. Nauk ArmSSR* **21,** 1, 15–20, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4558.

A generalization of the work of E. N. Blinova [*Ref. Zh. Mekh.* 1954, Rev. 3378] is presented, consisting in introducing the influence of vertical turbulent mixing on the formation of the baric field.

Author starts from the equation of the vertical component of the velocity vortex Ω_z, the additive term describing the effect of vertical mixing being retained. The equation is linearized for West-East transport and then integrated along the vertical coordinate z from $z = 0$ to $z = \infty$. In this integration, the boundary conditions are $\rho w = 0$ for $z = 0$ and $z = \infty$ (ρ – density, w – vertical velocity). The equation obtained as a result of integration contains the additive term

$$\nu \left.\frac{\partial \Omega_z}{\partial_z}\right| z = 0 \qquad [*]$$

where ν = kinematic viscosity.

This additive term is calculated by applying the equations of N. E. Kochin [*Tr. Gl. geofiz. observ.* 1935, no. 4], on the assumption that ν = const. These equations enable the horizontal components of the velocity in the planetary boundary layer to be expressed by the pressure gradient. Substituting in the above expression [*] the expressions obtained for the horizontal velocity components, and applying the barometric formula to transform the pressure at any arbitrary level into the pressure at sea level and temperature (the latter is assumed known), author obtains a linear inhomogeneous equation for determining the ground-level pressure. The solution is written as a series in spherical functions.

Courtesy Referativnyi Zhurnal S. A. Mashkovich, USSR
Translation, courtesy Ministry of Supply, England

4232. Zierep, J., Method for estimating approximately the lee wave flow for any given ground velocity (in German), *Z. Flugwiss.* **1,** 1, 9–11, June 1953.

A method is discussed for estimating approximately the lee wave flow for any given ground velocity $u(z)$ by calculating layer by layer. During this process, surfaces of separation between the various horizontal layers occur. The kinematic and dynamic conditions of the boundary surfaces and also the stability of such layers are discussed.

From author's summary

Lubrication; Bearings; Wear

(See also Rev. 4145)

4233. Kunert, K., Decrease of the radial clearance and of the shrink stress in anti-friction bearings operating at very high speeds (in German), *ZVDI* **99,** 13, 587–591, May 1957.

The increase in the radius of an inner race operating at very high speeds has usually been calculated without taking into account the radial stresses originating from the interference fit on the shaft, and from the thickness of the race, where that is not small relative to the diameter. Author derives equations to take these radial stresses also into account. He calculates their effect for bearings shrunk on a solid and a hollow shaft, and derives the speed at which the inner race becomes loose. The results are in better agreement with practical experience than earlier analyses which gave too high values for loss in radial clearance and decrease in shrunk stress with increasing speed.

A. G. Cattaneo, USA

4234. Ott, H. H., Tests on a bearing having three wedge films, *Brown Boveri Rev.* **44,** 4/5, 225–234, Apr./May 1957.

A new test rig for large turbine journal bearings is described, and tests of a journal bearing which is provided with three wedge-film-bearing areas separated by lubricant feed grooves are reported. Particulars were: diameter of journal 355 mm, width/diameter ratio 1.15, clearance ratio 0.001 2, speeds 1000, 2000, and 3000 rev/min, loads 1.45, 11, and 20.5 bars. Three values of lubricant feed pressure were used. Because, with this particular form of bearing, eccentricity is expected to be low, power was calculated from the torque measured at the bearing. Conventional friction/duty-parameter curves were obtained and feed pressure had negligible effect on the results when presented in this manner. The feed pressure had considerable effect on the amount of oil passed through the test bearing but a novel nondimensional plot is used to relate the results. It is claimed that the temperature rise through the bearing may be calculated on the basis that all heat is removed by the lubricating oil.

Reviewer considers that the method of test employed is not entirely representative of turbine practice because the single bearing used has greater freedom to tilt relative to shaft axis.

F. T. Barwell, Scotland

4235. Vogelpohl, G., On the load-carrying capacity of bearings and its calculation (in German), Forschungsberichte des Wirtschafts- und Verkehrsministeriums Nordhein-Westfalen no. 268, 66 pp., 1956.

Author first reviews general early history and recent German work on journal bearing design criteria, much of which is based on the $p \cdot v$ factor (mean bearing pressure × surface velocity). After consideration of the significance of the load-capacity concept in relation to bearing testing machines *and* practical operating requirements, he develops a criterion based on minimum permissible film thickness.

By reference to a wide range of experimental evidence, drawn mainly from the work of Gümbel, McKee and Stribeck, he concludes that, for journal bearings which have a length/diameter ratio $B/D > \frac{1}{2}$, good surface finish and sufficient clearance to operate at a relative eccentricity of about 0.95, the permissible mean bearing load P kg is given by

$$P = C \cdot \eta \cdot N \cdot Vol;$$

viscosity η centipoise, speed N rpm, volume $(Vol)\ BD^2\pi/4$ litres, and C a quantity dependent on minimum film thickness; for normal bearing design $C = 1$, but with special materials and production quality $C = 3$. Buske's work [*Stahl und Eisen* **71**, 1420–33, 1951] is discussed, showing that shaft bending effects can be neglected. Seven examples illustrate the design method, ranging from air-bearings to heavy-duty cement-kiln bearings.

Although many aspects of bearing design are not discussed, such as the effects of pressure- and temperature-viscosity characteristics of the lubricant and the positioning of oil grooves, reviewer considers that this paper merits translation and republication to reach English-speaking bearing designers.

G. D. S. MacLellan, England

4236. Pigott, R. J. S., and Walsh, S. R, Universal bearing tester, *Trans. ASME* **79,** 6, 1267–1274, Aug. 1957.

Many bearing testers of one type or another have been devised by those who have investigated bearings. Nearly all of these, from Thurston's old pendulum type through Kingsbury's, have been for unidirectional load only, and therefore are limited to just one of the three classes of load we need to know about. Most of the early machines lacked the precision now required for a study of bearing conditions. It will be perceived that since the coefficient of friction may be less than 0.001, a bearing tester for say 25,000-lb bearing load must have response to less than 0.25-lb friction force if accuracy is to be better than ±1%. Our initial work on bearing test machines was directed toward improving precision and sensitivity, but unidirectional loading was retained. Later it was recognized that the unidirectional load-test machine did not provide data representing dynamic loads of varying direction and magnitude. This led to the development of a rotation-load bearing test machine. The steps in this development are outlined in the paper.

From authors' summary

Marine Engineering Problems

(See also Rev. 3919)

4237. Granville, P. S., The viscous resistance of surface vessels and the skin friction of flat plates, *Shipbuilder* **64,** 589, 259–263, Apr. 1957.

Article is an abstract of a paper read before the SNAME Nov. 1956. Author's general conclusions are: The basic Froude hypothesis concerning the separation of viscous and wave-making resistances is justified within the accuracy of the test data. Any final decision as to the correct method of extrapolating model results to ship predictions can only be reached if more accuracy is reached in the experimental procedures.

H. W. Lerbs, Germany

4238. Munro-Smith, R., The draught-displacement curve and its derivatives in the design stages, *Shipbuilder* **64,** 586, 99–103, Feb. 1957.

Author provides formulas for approximating values at intermediate drafts of displacement, block coefficient, waterplane coefficient, tons per inch immersion, height of center of buoyancy above keel, transverse metacentric radius, moment of inertia about transverse axis, longitudinal metacentric radius, moment to change trim. Approximation is based on assumption of simple monomial representation for curve of waterplane areas having a conveniently chosen index and of a binomial representation for waterplane half-widths which neglects longitudinal asymmetry. Illustrative example is given.

Simple formulations presented are considered suitable for preliminary design of merchant vessels.

M. St. Denis, USA

4239. Cartwright, D. E., and Rydill, L. J., The rolling and pitching of a ship at sea, *Trans. Instn. nav. Arch. Lond.* **99,** 1, 100–135, Jan. 1957.

This paper provides information on the problem which dates back to the days of Froude and Kriloff, viz, "how much will a ship move in a given seaway?" The rolling and pitching of the *R.R.S. Discovery II* has been measured and the waves simultaneously recorded by a shipborne wave recorder. The preponderance of the observations were made at low speed on a number of courses in long-crested waves and also some results were obtained with the ship head-on to short-crested storm waves. A spectral analysis by means of an automatic Fourier analyser is carried out and an extension is made to show the connection between the spectra of ship motions and their statistical properties. Simplified theoretical relations as well as more complicated methods are compared with the results obtained from the measurements, with generally quite good correlation. This paper is substantially supplemented by a discussion provided by experts working in the field of seaworthiness largely through the use of small ship model experiments conducted in the United States.

J. P. Breslin, USA

4240. Voevodin, N. F., The differential equation of cubic capacity (in Russian), *Trudi Mosk. tekn. in-ta. ryb. prom-sti i kh-va* no. 6, 59–62, 1954; *Ref. Zh. Mekh.* 1956, Rev. 4485.

In designing ships for carrying bulky cargoes, it is desirable to avoid increasing the freeboard excessively. For this purpose the author suggests, in addition to the Bubnov equations, the use of a special equation linking cubic (hold) capacity and dynamic stability. The calculation for dynamic stability has been made by N. B. Sevastyanov, [cf. *Tr. Mosk. tekhn. in-ta. ryb. prom-sti i kh-va* no. 6, 63–96, 1954].

The differential equation of the cubic capacity is derived in the paper under review, it being assumed that the cubic capacities of all compartments of a prototype ship are available, and the required cubic capacity of the ship to be designed is determined. Practical indications for the application of the designed equation are given.

N. N. Babaev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

4241. Kane, J. R., and McGoldrick, R. T., Longitudinal vibrations of marine propulsion-shafting systems, *David W. Taylor Mod. Basin Rep.* 1088, 60 pp., Nov. 1956.

Paper concerns longitudinal vibration of system comprising propeller, main shafting, and propulsive machinery due to periodic variation of propeller thrust. Problem arises mainly in geared-turbine-driven or turbo-electric vessels having high power per shaft. Purpose of paper is to describe (a) how vibration analysis may be attempted using improved methods, and (b) what steps can be taken to reduce excitation. Conventional methods of vibration analysis are employed, article being essentially one on marine engineering. As such, it undoubtedly represents a major contribution.

R. E. D. Bishop, England

4242. Lerbs, H., Results of the applied theory of ship propellers (in German), *Jahrbuch Schiffbautech. Gesellsch.* **49,** 163–206, 1955.

Author gives a complete review of the developments and of the practical results of the modern theory of the ship propeller. He especially considers the free propeller and the wake propeller, both with minimum energy loss. He points out the great value of this theory, which permits analyzing the characteristics of the flow at each blade section, in order to choose the best solutions for vibration and cavitation problems.

R. G. A. Spronck, Belgium

4243. Ward, L. W., Methods for estimating impact forces on ship appendages, *Exp. Towing Tank Rep.* no. 616, 43 pp., Dec. 1956.

In design of ship appendages such as sponsons or gun emplacements mounted on side of vessel, strength required is dictated by forces resulting from impact of appendage on water surface. It is

assumed that velocity of penetration is constant and hence force is defined solely in terms of rate of change of virtual mass. A large number of papers written on this subject are briefly reviewed in this paper. Most reasonable values of impact force coefficient to use in design are presented along with method for obtaining most probable entry velocity. Author concludes that a complete solution for relative ship-wave velocity pattern must be made in every case. Examples of calculation of forces on appendages are given. In every case values are much greater than the currently used criterion of 1000 lb/sq ft.

Reviewer believes paper will be of wider interest than just to naval architects for whom it was written. Any engineer having to design structures for hydrodynamic impact will find it useful.

W. D. Baines, Canada

4244. Freimanis, E., and Lindgren, H., Systematic tests with ship models with $\delta_{pp} = 0.675$, *Medd. Stat. SkeppsProvAnst.* no. 39, 47 pp., 1957.

Letters to the Editor

4245. Concerning AMR 10, Review 2062 (July 1957): Seames, A. E., and Conway, H. D., A numerical procedure for calculating the large deflections of straight and curved beams.

The reviewer remarks that: "For a straight cantilever with end load, a table with 14 columns is required to find the length of a beam with given angular deflection under the load. Several such tables would be required to solve the direct problem of finding the deflection for a beam of given length."

The junior author would like to point out that a number of the 14 columns referred to were inserted in the paper only for completeness. For instance, the first column gives the projected length p per element which is chosen arbitrarily as unity in all cases but one; the second gives the reciprocal of the radius of curvature R; the third the radius of curvature R; the fourth p/R, and so on. The calculations are so simple that a table can be completed in a matter of minutes.

So far as the second point is concerned, it is not necessary to compute more than a few tables since graphs of X/L and Y/L versus WL^2/EI (paper's nomenclature) will apply to *any* initially straight cantilever under *any* initially normal end load.

H. D. Conway, USA

Books Received for Review

BARWELL, F. T., Lubrication of bearings, London, Butterworths Scientific Publications, 1956, xii + 292 pp.

Behavior of metals at elevated temperatures, New York, Philosophical Library, Inc., vii + 122 pp. $6.00.

GARSIDE, J. E., Process and physical metallurgy, second edition, revised, London, Charles Griffin & Company, Ltd., 1957, xx + 593 pp. 54s.

HAUSEN, H. Wärmeübertragung im Gegenstrom, Gleichstrom und Kreuzstrom, Technische Physik in Einzeldarstellungen, Berlin, Springer-Verlag, 1950, xii + 464 pp.

HUTCHINSON, F. W., Thermodynamics of heat-power systems, Reading, Massachusetts, Addison-Wesley Publishing Company, Inc., 1957, xix + 490 pp. $8.50.

Jahrbuch der Schiffbautechnischen Gesellschaft, Vol. 50, Berlin, Springer-Verlag, 1956, 345 pp. $12.00.

JAKOB, M., and HAWKINS, G. A., Elements of heat transfer, third edition, New York, John Wiley & Sons, 1957, xxv + 317 pp. $6.75.

KAY, J. M., An Introduction to fluid mechanics and heat transfer, New York, Cambridge University Press, xvi + 309 pp. $7.00.

LANDSHOFF, R. K. M., edited by, Magnetohydrodynamics, Stanford, Calif., Stanford University Press, 1957, x + 115 pp. $4.00.

MAURI, H., Der Vorrichtungsbau, I. Einteilung, Aufgaben und Elemente der Vorrichtungen, sixth revised, improved edition, Berlin, Springer-Verlag, 1957, 70 pp. DM 3.60.

MUNSTER, A., Statistische Thermodynamik, Berlin, Springer-Verlag, 1956, x + 852 pp.

NEWTON, G. C., Jr., GOULD, L. A., and KAISER, J. F., Analytical design of linear feedback controls, New York, John Wiley & Sons, Inc., 1957, xi + 419 pp. $12.00.

PFLEIDERER, C., Strömungsmaschinen, second revised edition, Berlin, Springer-Verlag, 1957, xiv + 421 pp.

Proceedings of the Second European Aeronautical Congress, Vol. I, II, III, Scheveningen, September 25–29, 1956, 560 pp., 557 pp., 313 pp.

SHANLEY, F. R., Strength of materials, New York, McGraw-Hill Book Company, Inc., 1957, xxiii + 783 pp. $8.50.

STEPHENS, R. C., and WARD, J. J., Applied mechanics, London, Cleaver-Hume Press, Ltd., 1957, xii + 244 pp. 12s. 6d.

TROSKOLANSKI, A. T., Hydromechanika Techniczna, Tom III, Pomiary Wodne, Warszawa, Panstowowe Wydawnictwa Techniczne, 1957, xxiv + 662 pp.

WATSON, G. O., Marine electrical practice (Marine engineering series), New York, Philosophical Library Inc., 1957, viii + 325 pp. $12.00.

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